DSN Telecommunications Link
Design Handbook

104, Rev. E
34-m BWG Stations
Telecommunications Interfaces

Released: September 15, 2009

Prepared by:

S. D. Slobin 9-9-2009

S. D. Slobin, Date
Antenna System Engineer

Approved by:

9/9/09

Timothy T. Pham Date
DSN Chief System Engineer

Released by:

Signature on file at DSN Library 9/15/09

DSN Document Release Date

Change Log

Rev	Issue Date	Affected Paragraphs	Change Summary
Initial	11/30/2000	All	All
A	2/5/2004	All	Added performance information for Ka-Band capability at DSS 26 and for new station, DSS 55. Incorporated latest measurements for other stations. Incorporated text improvements.
B	8/1/2005	Tables 4, 5, A-1, A-2, A-3, Figures 4, 9, 14, 20, and 25.	Revised performance information for DSS 34 to reflect addition of Ka-band and X-band improvements. Required splitting of Table 4 into Tables 4 and 5, renumbering subsequent tables, revision of Figures 9 and 20, and addition of Figures 4, 14, and 25.
C	9/19/2008	Sections 2.1.3, 3.0; All Tables; Figures 1, 3, 4, 6 - 27	Documents installation of an X-band acquisition capability at DSS 24, 34, and 54. Revised T_{AMW} formulation for noise temperature to be consistent with Rev. B of module 105. Added proposed 26 GHz capability at DSS 24, 34, and 54.
D	5/15/2009	Tables 6, 11 Figures 13-15, 27-29, 36 Table A-3	Add K-band gain and noise temperature performance for DSS 24, 34, and 54
E	9/15/2009	Table A-4	Updated Ka-band G and T parameters for DSS 54 and DSS 55. HEMT numbering has also been corrected in that Table.

Note to Readers

There are two sets of document histories in the 810-005 document that are reflected in the header at the top of the page. First, the entire document is periodically released as a revision when major changes affect a majority of the modules. For example, this module is part of 810-005, Revision E. Second, the individual modules also change, starting as an initial issue that has no revision letter. When a module is changed, a change letter is appended to the module number on the second line of the header and a summary of the changes is entered in the module's change log.

Contents

Illustrations

Illustrations (Continued)

Illustrations (Continued)

Tables

Tables (Continued)

1 Introduction

1.1 Purpose

This module provides the performance parameters for the Deep Space Network (DSN) 34-m Beam Waveguide (BWG) antennas and the 34-m High-speed BWG (HSB) antenna that are necessary to perform the nominal design of a telecommunications link. It also summarizes the capabilities of these antennas for mission planning purposes and for comparison with other ground station antennas.

1.2 Scope

The scope of this module is limited to providing those parameters that characterize the RF performance of the 34-meter BWG and HSB antennas including the effects of weather for a limited number of weather conditions. A more complete discussion of weather effects is given in module 105, Atmospheric and Environmental Effects. This module does not discuss mechanical restrictions on antenna performance covered in module 302, Antenna Positioning.

2 General Information

The 34-meter diameter BWG (beam waveguide) and HSB (high angular-tracking speed beam waveguide) antennas are the latest generation of antennas built for use in the DSN. These antennas differ from more conventional antennas (for example, the 34-meter HEF antennas, described in module 103) in the fact that a series of mirrors, approximately 2.4 meters in diameter, direct microwave energy from the region above the main reflector to a location in a pedestal room at the base of the antenna. The pedestal room is located below the azimuth track of the antenna and is, with the exception of the HSB antenna, below ground level.

In this configuration, several “positions” of microwave equipment contained in the pedestal room can be accessed by rotation of an ellipsoidal mirror located in the center of the pedestal room floor beneath the azimuth axis of the antenna. This enables great versatility of design and allows tracking with equipment at one position while equipment installation or maintenance is carried out at the other positions. Since cryogenic low-noise amplifiers (LNAs) do not tip as they do when located above the elevation axis, certain state-of-the-art, ultra low noise amplifier (ULNA) and feed designs can be implemented.

The HSB antenna differs from the BWG antennas in that the pedestal room is above ground level, the microwave optics design is different, and the subreflector does not focus automatically for the purpose of maintaining gain as the elevation angle of the antenna changes. The HSB antenna has higher tracking rates than do the BWG antennas and is equipped primarily for tracking Earth-orbiting satellites.

The capabilities of each antenna differ depending on the microwave, transmitting, and receiving equipment installed. A summary of these differences is provided in Table 1. Functional block diagrams for each antenna are provided in Figures 1–5. In general, each antenna has one LNA for each supported frequency band. However, stations that can support simultaneous right circular polarization (RCP) and left circular polarization (LCP) in the same band have an LNA for each. In addition, the stations that support Ka-Band contain an additional LNA to enable monopulse tracking when using RCP polarization. Each antenna also has at least one transmitter. Antennas with more than one transmitter can operate only one of them at a time. DSS 25 is an exception and has a Ka-Band transmitter that can be operated at the same time as its X-Band transmitter.

There are four stations, DSS 24, 27, 34, and 54, that are capable of receiving selectable (one polarization at a time) RCP or LCP at S-band. Three of these, DSS 24, 34, and 54, are capable of simultaneously or independently receiving selectable (one polarization at a time) RCP or LCP at X-band. The remaining BWG stations, DSS 25, 26, and 55, can receive both X-band polarizations simultaneously. K-band (26 GHz) receive capability with selectable (one polarization at a time) RCP or LCP exists at DSS 24 and DSS 34, and DSS 54 will be equipped with this capability before the end of 2009. Ka-band capability including monopulse-assisted tracking of RCP signals exists at DSS 25, 26, 34, 54, and 55. DSS 26, 34, 54, and 55 can also receive Ka-band LCP either for telemetry without monopulse assisted tracking or simultaneously with Ka-band RCP for radio science investigations. There is no capability to process telemetry from both Ka-band polarizations simultaneously at any station and DSS 25 cannot receive Ka-band LCP

The 26 GHz receive capability can be used independently or in combination with the station's S-band capability to provide a high-rate return link capability for spacecraft operating at less than 2×10^6 km (near-Earth) ranges. A low gain mode is included to accommodate high signal levels that are expected during the early post-launch phase of 26 GHz missions. Neither the X-band receive capability at DSS-24, nor the X-band or Ka-band receive capabilities at DSS 34 and 54 are available when K-band receive is being used at these stations.

The S- Band transmitters at all S-band stations (DSSs 24, 27, 34, and 54) and the X-band transmitter at DSS 24 and 25 are coupled into the microwave path using a frequency-selective diplexer. Because the diplexer increases the operating system temperature, a non-diplexed path for receive-only operation is provided at all of these antennas, except the DSS 27 HSB antenna. The X-band diplexing function at DSSs 26, 34, 54, and 55 is accomplished using the frequency-selective characteristics of the feed in conjunction with an external polarizing network. This technique does not affect the operating system temperature so they are considered to be always diplexed and no lower-noise, non-diplexed, configuration is necessary or available.

When an S-Band uplink is required, the received S-band polarization must be the same as is being transmitted. X-Band uplinks can be of either polarization independent of the polarization or polarizations of any signals being received. S-Band downlinks are not available in conjunction with X-Band uplinks due to bandwidth restrictions of the S/X dichroic plate. This dichroic plate must be retracted for X-Band uplink operation.

The S-band transmitters at DSS 24, 34, and 54, when operated near their maximum power rating, produce sufficient 13th harmonic power to adversely affect telemetry reception in the 26 GHz band. Mission designers selecting an uplink frequency between 2025 and 2076.9 MHz and requiring a radiated power in excess of 5.0 kW should select a downlink frequency such that the 13th harmonic of the uplink frequency does not fall within the bandwidth required for their telemetry.

When simultaneous X-Band uplink and downlink of the same polarization are required at stations with waveguide diplexers (DSS 24 and 25), reception must be through the diplexer, and the noise will be increased over that of the non-diplexed path. These stations have two X-Band LNAs and can receive simultaneous RCP and LCP, although one of the signals will be via the non-diplexed path and the other will be via the diplexed path. DSSs 26, 34, 54, and 55 also have two X-Band LNAs, one for each polarization. As these stations do not have waveguide diplexers, the noise level in each polarization is approximately the same. Although there are two X-band LNAs at DSS 34 and DSS 54, there is only one X-band receiver, so simultaneous RCP and LCP reception is not possible.

2.1 Telecommunications Parameters

The significant parameters of the 34-meter BWG and HSB antennas that influence the design of the telecommunications link are listed in Tables 2 through 9. Variations of these parameters that are inherent in the design of the antennas are discussed below. Other factors that degrade link performance are discussed in modules 105 (Atmospheric and Environmental Effects) and 106 (Solar Corona and Solar Wind Effects).

The values in these tables do not include the effects of the atmosphere. However, the attenuation and noise-temperature effects of weather for three specific weather conditions are included in the figures at the end of the module so that they may be used for a quick estimate of telecommunications link performance for those specific conditions, without reference to module 105. For detailed design control table use, the more comprehensive and detailed S-, X-, K-, and Ka -band weather effects models (for weather conditions up to 99% cumulative distribution) in module 105 should be used.

2.1.1 Antenna Gain Variation

Because the gain is referenced to the feedhorn aperture, such items as diplexers and waveguide runs to alternate LNAs, that are "downstream" (below the feedhorn aperture, toward the LNA), do not affect the gain at the reference plane. Dichroic plates that are "upstream" of the feedhorn aperture cause a reduction in gain.

2.1.1.1 Frequency Effects

Antenna gains are specified at the indicated frequency (f_0). For operation at higher or lower frequencies in the same band, the gain (dBi) must be increased or reduced, respectively, by 20 log (f/f_0).

2.1.1.2 Elevation Angle Effects

Structural deformation causes a reduction in gain when the antenna is operated at an elevation angle other than where the reflector panels were aligned. The effective gain of the antenna also is reduced by atmospheric attenuation, which is a function of elevation. Figures 6 through 19 show representative curves of gain versus elevation angle for selected stations and configurations. The gain curves show the hypothetical vacuum (no atmosphere) condition, and the gain with 0%, 50%, and 90% weather conditions, designated as CD (cumulative distribution) = 0.00, 0.50, and 0.90. 0% means minimum weather effect (exceeded 100% of the time); 90% means that effect which is exceeded only 10% of the time. Qualitatively, 0% corresponds to the driest, lowest-loss condition of the atmosphere; 25% corresponds to average clear; 50% corresponds to humid or very light clouds; and 90% corresponds to very cloudy, but with no rain. Appendix A provides the complete set of parameters from which these curves were created. These parameters, in combination with the weather effects parameters from module 105, can be used to calculate the gain versus elevation angle curve for any antenna, in any configuration, for weather conditions up to 99% CD.

2.1.1.3 Wind Loading

The gain reduction at X-Band due to worst-case wind loading is listed in Table 10. The tabular data are for structural deformation only and presume that the antenna is maintained on-point. In addition to structural deformation, wind introduces a pointing error that is related to the antenna elevation angle, the angle between the antenna and the wind, and the wind speed. The effects of pointing error are discussed below. Cumulative probability distributions of wind velocity at Goldstone are given in module 105.

2.1.2 *System Noise Temperature Variation*

The operating system temperature (T_{op}) varies as a function of elevation angle due to changes in the path length through the atmosphere and ground noise received by the sidelobe pattern of the antenna. Figures 20 through 33 show the combined effects of these factors for the same set of stations and configurations selected above. The figures show the antenna and microwave contribution alone, and also the system operating noise temperature (T_{op}) with 0%, 50%, and 90% weather conditions. The equations and parameters for these curves are provided in Appendix A and can be used, in combination with the weather effects parameters from module 105, to calculate the system temperature versus elevation curve for any antenna, in any configuration, for weather conditions up to 99% CD. The values of zenith atmospheric attenuation (A_{zen}) used in generating these figures are given in Table A-5.

The system operating noise temperature, T_{op}, consists of two parts, an *antenna-microwave component*, T_{AMW}, for the contribution of the antenna and microwave hardware only, and a *sky component*, T_{sky}, that consists of the atmosphere noise, plus the cosmic microwave background (CMB) noise attenuated by the atmosphere loss. T_{AMW} is shown in Figures 20 through 33 as “ANT-UWV”. The system operating noise temperature is given by

$$T_{op}(\theta) = T_{AMW} + T_{sky} = \left[T_1 + T_2 e^{-a\theta}\right] + \left[T_{atm}(\theta) + T'_{CMB}(\theta)\right]$$

where

T_1, T_2 and a are coefficients and exponent given in Appendix A, Tables A-1, A-2, A-3, and A-4.

T_{atm} is the atmosphere contribution term, calculated from Module 105

T'_{CMB} is the attenuated cosmic contribution, calculated from Module 105

More details of this calculation are given in Appendix A of this module.

The T_{AMW} noise temperature values in Tables 6 through 9 are stated with reference to the feedhorn aperture and arise from antenna and microwave hardware contribution only. No atmosphere or cosmic background contribution is included. Table 11 presents values of T_{AMW}, T_{sky}, and T_{op} for all antenna frequencies and configurations at zenith, with average-clear CD = 0.25 weather. The values of T_{sky} in Table 11 are calculated by methods presented in Module 105, using year-average attenuation values of that module. The values of A_{zen} used in calculating T_{sky} for CD = 25% average clear weather are given in Table A-5.

2.1.3 *Antenna Pointing*

2.1.3.1 *Pointing Accuracy*

The pointing accuracy of an antenna, often referred to as its *blind-pointing* performance, is the difference between the calculated (or commanded) beam direction and the actual beam direction. The error is typically random and can be divided into two major categories. The first of these includes the computational errors and uncertainties associated with the radio sources used to calibrate the antenna, and the location of the spacecraft provided by its navigation team. The second has many components associated with converting a calculated beam direction to the physical positioning of a large mechanical structure. Included are such things as atmospheric wind and refraction effects, servo and encoder errors, thermally and gravitationally induced structural deformation, azimuth track leveling (for an azimuth-elevation antenna), and both seismic and diurnal ground tilt.

Blind pointing is modeled by assuming equal pointing performance in the elevation (EL) and cross-elevation (X-EL) directions. That is, the random pointing errors in each direction have uncorrelated Gaussian distributions with the same standard deviation. This results in a Rayleigh distribution for pointing error where the mean radial error is 1.2533 times the standard deviation of the EL and X-EL components. For a Rayleigh distribution, the probability that the pointing error will be less than or equal to the mean radial error is 54.4%. Conversely, the probability that the mean radial error will be exceeded is 45.6%.

810-005 module 302 (Antenna Positioning) presents blind pointing performance (mean radial error) for the DSN antennas.

2.1.3.2 Pointing Loss

Figures 34 through 36 show the effects of pointing error on effective transmit and receive gain of the antenna. These curves are Gaussian approximations based on measured and predicted antenna beamwidths. Data have been normalized to eliminate elevation and wind loading effects. The equations used to derive the curves are provided in Appendix A.

2.1.3.3 Monopulse-aided Pointing

Ka-Band monopulse-aided pointing uses a monopulse tracking coupler within the cryogenic feed package to establish a feed pattern with a theoretical null on axis. The magnitude of the pointing error is proportional to the magnitude of the signal received by this pattern and the azimuthal error is proportional to the phase difference between the sum and difference outputs of the coupler. Thus, by measuring the complex ratio of the sum and difference signals, pointing corrections can be generated to instruct the antenna servo system to drive the pointing error to zero. The system achieves its specified performance when the ratio of the signal in the sum channel (that is, the signal from which tracking and telemetry information will be derived) to the noise level in the difference channel is 26 dB-Hz.

2.1.3.4 Ka-Band Aberration Correction

The extremely narrow beamwidth at Ka band requires that a Ka-Band uplink signal be aimed at where the spacecraft will be when the signal arrives, while simultaneously receiving a signal that left the spacecraft one one-way light-time previously. This is accomplished by mounting the Ka-Band transmit feed at DSS 25 on a movable X-Y platform that can displace the transmitted beam as much as 30 millidegrees from the received beam. DSS 25 is the only antenna with a Ka-Band transmit capability. The fact that the transmit feed is displaced from its optimum focus causes the gain reduction depicted in Figure 37. The equation used to generate this curve is provided in Appendix A.

2.1.3.5 X-band Acquisition

A 1.2-m X-band acquisition antenna and receiver has been installed at the apex (above the subreflector) of the DSS 24, DSS 34, and DSS 54 antennas. The acquisition receiver employs the monopulse technique to develop pointing commands for the antenna during the launch phase when launch time and trajectory uncertainties make predict-driven pointing impractical. During acquisition, the acquisition system is responsible for antenna pointing, however forward and return link services are provided by the main antenna beam. The characteristics of the acquisition antenna are given in Table 7 (for DSS 24) and in Table 8 (for DSS 34 and DSS 54).

3 Proposed Capabilities

The DSN is in the process of increasing the number of 34-m BWG antennas. The first two of these antennas will be built at the Canberra DSCC and will be functional equivalents to the DSS 55 antenna at the Madrid DSCC. The first of these antennas is expected to become operational in 2014.

Table 1. Summary of Available Configurations for Each Antenna.

Configuration	**Uplink***	**Downlink**		**Remarks**
		Band	Polarization	
DSS 24 (BWG)				
S-Up, S-Down	S, 18.4 kW	S	RCP or LCP	• Transmit and receive polarizations must be the same
S-Up, S/X-Down	S, 18.4 kW	S	RCP or LCP	• S-band transmit and receive polarizations must be the same. • X-band may use low noise (non-diplexed) or diplexed path.
		X	RCP or LCP	
S-Up, K-Down	S, 18.4 kW	S	RCP or LCP	• S-band transmit and receive polarizations must be the same. • Both K-band polarizations have similar noise characteristics.
		K	RCP or LCP	
S-Down Low Noise with or without X or K downlink	None	S	RCP or LCP	• Non-diplexed path
		X	RCP or LCP	• X-band may use low noise (non-diplexed) or diplexed path.
		K	RCP or LCP	• Both K-band polarizations have similar noise characteristics
X-Up, X-Down	X, 18.2 kW	X	RCP or LCP	• Transmit and receive polarizations are independent. • Requires S/X dichroic plate to be retracted – no S-band.
X-Down Low Noise	None	X	RCP or LCP	• Non-diplexed path with S/X dichroic plate retracted
K-Down, Low Noise	None	K	RCP or LCP	• Requires S/K dichroic plate to be retracted – no S-band. • Both K-band polarizations have similar noise characteristics
DSS 34 and DSS 54 (BWG)				
S-Up, S-Down	S, 18.4 kW	S	RCP or LCP	• Transmit and receive polarizations must be the same
S-Up, S/X-Down	S, 18.4 kW	S	RCP or LCP	• S-band transmit and receive polarizations must be the same. • Both X-band polarizations have similar noise characteristics
		X	RCP or LCP	
S-Up, K-Down	S, 18.4 kW	S	RCP or LCP	• S-band transmit and receive polarizations must be the same. • Both K-band polarizations have similar noise characteristics.
		K	RCP or LCP	

- The power listed in this column refers to the maximum available uplink power at the feedhorn aperture, accounting for waveguide loss between transmitter output and feedhorn aperture.

Table 1. Summary of Available Configurations for Each Antenna (Continued).

Configuration	Uplink*	Downlink		Remarks
		Band	Polarization	
DSS 34 and 54 (BWG), Continued				
S-Down Low Noise with or without X or K downlink	None	S	RCP or LCP	• Non-diplexed path
		X	RCP or LCP	• Both X-band polarizations have similar noise characteristics
		K	RCP or LCP	• Both K-band polarizations have similar noise characteristics
X-Up, X-Down	X, 17.4 kW	X	RCP or LCP	• Transmit and receive polarizations are independent. • Feed diplexer does not affect noise characteristics
K- Down, Low Noise	None	K	RCP or LCP	• Requires S/K dichroic plate to be retracted – no S-band. • Both K-band polarizations have similar noise characteristics
X-Up, X/Ka-Down, Ka-Monopulse	X, 17.4 kW	X	RCP or LCP	• X-band transmit and receive polarizations are independent. • Monopulse is optionally available for Ka-band RCP.and prevents use of LCP
		Ka	RCP only	
X-Up, X/Ka-Down, Dual Polarization	X, 17.4 kW	X	RCP or LCP	• X-band transmit and receive polarizations are independent. • Simultaneous Ka RCP and LCP prevents use of monopulse
		Ka	RCP and LCP	
DSS 25 (BWG)				
X-Up, X-Down	X, 18.2 kW	X	RCP and LCP	• Polarization that matches transmit uses higher noise diplexed path • Opposite (to transmit) polarization uses low noise (non-diplexed) path.
X-Down Low Noise	None	X	RCP and LCP	• One polarization is low noise (via non-diplexed path). • Opposite polarization is available via higher noise diplexed path.
X/Ka-Down, Ka-Monopulse	None	X	RCP and LCP	• One X-band polarization is low noise (via non-diplexed path). • Opposite polarization is available via higher noise diplexed path. * Use of monopulse is optional
		Ka	RCP only	

• The power listed in this column refers to the maximum available uplink power at the feedhorn aperture, accounting for waveguide loss between transmitter output and feedhorn aperture.

Table 1. Summary of Available Configurations for Each Antenna. (Continued)

Configuration	Uplink*	Downlink		Remarks
		Band	Polarization	
DSS 25 (BWG), Continued				
X-Up, X/Ka-Down, Ka-Monopulse	X, 18.2 kW	X	RCP and LCP	• Polarization that matches transmit uses higher noise diplexed path • Opposite (to transmit) polarization uses low noise (non-diplexed) path. * Use of monopulse is optional
		Ka	RCP only	
X/Ka-Up, X/Ka-Down, Ka-Monopulse	X, 18.2 kW Ka, 755 W, LCP	X	RCP and LCP	• X-band polarization that matches transmit uses higher noise diplexed path • Opposite (to X-band transmit) polarization uses low noise (non-diplexed) path. • Use of monopulse is optional. • Ka-Up is reconfigurable to RCP
		Ka	RCP only	
Ka-Up, Ka-Down, Ka-Monopulse	Ka, 755 W, LCP	Ka	RCP only	• Lowest noise configuration (X/Ka dichroic plate retracted) • Use of monopulse is optional • Ka-Up is reconfigurable to RCP
DSS 26 and DSS 55 (BWG)				
X-Up, X-Down	X, 17.4 kW	X	RCP and LCP	• Transmit and receive polarizations are independent. • Both X-band receive polarizations are available with similar noise characteristics.
X-Up, X/Ka-Down, Ka-Monopulse	X, 17.4 kW	X	RCP and LCP	• Transmit and receive polarizations are independent. • Feed diplexer does not affect noise characteristics. • Both X-band receive polarizations are available with similar noise characteristics. • Monopulse is optional for Ka-band RCP.
		Ka	RCP only	
X-Up, X/Ka-Down, Dual Polarization	X, 17.4 kW	X	RCP and LCP	• X-band transmit and receive polarizations are independent. • Both X-band receive polarizations are available with similar noise characteristics. • Both Ka-band receive polarizations are available with similar noise characteristics. • Simultaneous RCP and LCP prevents use of monopulse.
		Ka	RCP and LCP	
		Ka	RCP only	

* The power listed in this column refers to the maximum available uplink power at the feedhorn aperture, accounting for waveguide loss between transmitter output and feedhorn aperture

Table 1. Summary of Available Configurations for Each Antenna (Continued).

Configuration	**Uplink***	**Downlink**		**Remarks**
		Band	Polarization	
DSS 26 and DSS 55 (BWG), Continued				
X/Ka-Down, Ka-Monopulse	None	X	RCP and LCP	• Both X-band receive polarizations are available with similar noise characteristics. • Monopulse is optional for Ka-band RCP.
X/Ka-Down, Dual Polarization	None	X	RCP and LCP	• Both X-band receive polarizations are available with similar noise characteristics. • Both Ka-band receive polarizations are available with similar noise characteristics. • Simultaneous RCP and LCP prevents use of monopulse.
		Ka	RCP and LCP	
DSS 27 (HSB)				
S-Up, S-Down	S, 174 W	S	RCP or LCP	• Transmit and receive polarizations must be the same.

* The power listed in this column refers to the maximum available uplink power at the feedhorn aperture, accounting for waveguide loss between transmitter output and feedhorn aperture

Table 2. S-Band Transmit Characteristics, DSS 24, 34, and 54

Parameter	Value	Remarks
ANTENNA		
Gain at 2115 MHz	56.25 +0.2,–0.3 dBi	At peak of gain versus elevation curve, referenced to feedhorn aperture for matched polarization; no atmosphere included; triangular probability density function (PDF) tolerance.
Transmitter Waveguide Loss	0.6 ±0.1 dB	20-kW transmitter output terminal (waterload switch) to feedhorn aperture
Half-Power Beamwidth	0.263 ±0.020 deg	Angular width (2-sided) between half-power points at specified frequency
Polarization	RCP or LCP	One polarization at a time, remotely selected. Polarization must be the same as received polarization.
Ellipticity	1.0 dB (max)	Peak-to-peak axial ratio defined as the ratio of peak-to-trough received voltages with a rotating linearly polarized source and the feed configured as a circularly (elliptically) polarized receiving antenna.
Pointing Loss		
Angular	See module 302	See also Figure 34.
CONSCAN	0.01 dB	X-Band CONSCAN reference set for 0.1 dB loss
	0.1 dB	S-Band CONSCAN reference set for 0.1 dB loss
EXCITER AND TRANSMITTER		
Frequency Range Covered	2025–2120 MHz	Power amplifier is step-tunable over the specified range in six 20-MHz segments, with 5-MHz overlap between segments. Tuning between segments can be accomplished in 30 seconds.
Instantaneous 1-dB Bandwidth	20 MHz	

Table 2. S-Band Transmit Characteristics, DSS 24, 34, and 54 (Continued)

Parameter	Value	Remarks
EXCITER AND TRANSMITTER (Continued)		
Coherent with earth orbiter S-Band D/L allocation	2028.8–2108.7 MHz	240/221 turnaround ratio
Coherent with deep space S-Band D/L channels	2110.2–2117.7 MHz	240/221 turnaround ratio
Coherent with deep space X-Band D/L channels	2110.2–2119.8 MHz	880/221 turnaround ratio
RF Power Output		Referenced to 20-kW transmitter output terminal (waterload switch). Settability is limited to 0.25 dB by measurement equipment precision.
2025–2120 MHz	53.0–73.0 +0.0,–1.0 dBm	
Power output varies across the bandwidth and may be as much as 1 dB below nominal rating. Performance will also vary from tube to tube. Normal procedure is to run the tubes saturated, but unsaturated operation is also possible. The point at which saturation is achieved depends on drive power and beam voltage. The 20-kW tubes are normally saturated for power levels greater than 60 dBm (1 kW). Minimum power out of the 20-kW tubes is about 53 dBm (200 W). Efficiency of the tubes drops off rapidly below nominal rated output.		
EIRP (maximum)	128.65 +0.2, –1.0 dBm	At gain set elevation angle, referenced to feedhorn aperture
Tunability		At transmitter output frequency
Phase Continuous Tuning Range	2.0 MHz	
Maximum Tuning Rate	±12.1 kHz/s	
Frequency Error	0.012 Hz	Average over 100 ms with respect to frequency specified by predicts
Ramp Rate Error	0.001 Hz/s	Average over 4.5 s with respect to rate calculated from frequency predicts

Table 2. S-Band Transmit Characteristics, DSS 24, 34, and 54 (Continued)

Parameter	Value	Remarks
EXCITER AND TRANSMITTER (Continued)		
Stability		At transmitter output frequency
Output Power Stability		From initial calibration value over 8 hours at a fixed frequency
Saturated Drive	±0.3 dB peak	
Unsaturated Drive	±0.5 dB peak	
Output Power Variation		Across any 600 kHz segment
Saturated Drive	≤0.3 dB p-p	
Unsaturated Drive	≤0.5 dB p-p	
Group Delay Stability	≤ 3.5 ns rms	Ranging modulation signal path (see module 203) over 8 h period
Spurious Output	1–10 Hz -50 dB 10 Hz–1.5 MHz -60 dB 1.5 MHz–8 MHz -45 dB	Below carrier
2nd Harmonic	-85 dB	
3rd Harmonic	–85 dB	
4th Harmonic	–140 dB	At input to X-Band horn, with transmitter set for 20-kW output
13th Harmonic		The 13th harmonic of the transmitter lies within the 25.5 – 27.0 GHz allocation for transmitter frequencies from 2025 to 2076.9 MHz and is presently unfiltered

Table 3. S-Band Transmit Characteristics, DSS 27

Parameter	Value	Remarks
ANTENNA		
Gain at 2070 MHz	54.34 +0.2, –0.3 dBi	At peak of gain versus elevation angle curve, referenced to feedhorn aperture for matched polarization; no atmosphere included; triangular PDF tolerance.
Transmitter Waveguide Loss	0.6 ±0.1 dB	200-W transmitter output terminal (waterload switch) to feedhorn aperture
Half-Power Beamwidth	0.269 ±0.020 deg	Angular width (2-sided) between half-power points at specified frequency
Polarization	RCP or LCP	One polarization at a time, remotely selected. Polarization must be the same as received polarization.
Ellipticity	1.0 dB (max)	Peak-to-peak axial ratio. See Table 2 for definition.
Pointing Loss		
Angular	See module 302	See also Figure 34.
EXCITER AND TRANSMITTER		
Frequency range covered	2025–2120 MHz	
Coherent with earth orbiter S-Band D/L allocation	2028.8–2108.7 MHz	240/221 turnaround ratio
Coherent with deep space S-Band D/L channels	2110.2–2117.7 MHz	240/221 turnaround ratio
RF Power Output	53.0, ±0.5 dBm	Referenced to 200 W transmitter output terminal (power load switch).
EIRP	106.74 ±0.6 dBm	At gain set elevation angle, referenced to feedhorn aperture

Table 3. S-Band Transmit Characteristics, DSS 27 (Continued)

Parameter	Value	Remarks
EXCITER AND TRANSMITTER (Continued)		
Tunability		At transmitter output frequency
Phase Continuous Tuning Range	2.0 MHz	
Maximum Tuning Rate	±12.1 kHz/s	
Frequency Error	0.012 Hz	Average over 100 ms with respect to frequency specified by predicts
Ramp Rate Error	0.001 Hz/s	Average over 4.5 s with respect to rate calculated from frequency predicts
Output Power Stability	±0.25 dB	Worst case over 8-h period using 30-m sample intervals
Spurious Output		Below carrier
2025–2120 MHz	–88 dB	
2200–2300 MHz	–94 dB	
2nd Harmonic	–60 dB	
3rd Harmonic	–60 dB	
8400–8500 MHz	–94 dB	

Table 4. X-Band Transmit Characteristics, DSS 24, 25, 26, 34, 54, and 55

Parameter	Value	Remarks
ANTENNA		
Gain at 7145 MHz	67.09 +0.2,–0.3 dBi	At peak of gain versus elevation angle curve, referenced to feedhorn aperture for matched polarization; no atmosphere included; triangular PDF tolerance.
Transmitter Waveguide Loss		20-kW transmitter output terminal (waterload switch) to feedhorn aperture
DSS 24, 25	0.4 ±0.1 dB	
DSS 26, 34, 54, 55	0.6 ±0.1 dB	
Half-Power Beamwidth	0.077 ±0.004 deg	Angular width (2-sided) between half-power points at specified frequency
Polarization	RCP or LCP	One polarization at a time, remotely selected, independent of received polarization.
Ellipticity	1.0 dB (max)	Peak-to-peak axial ratio. See Table 2 for definition.
Pointing Loss		
Angular	See module 302	See also Figure 35.
CONSCAN	0.1 dB	X-Band CONSCAN reference set for 0.1 dB loss
EXCITER AND TRANSMITTER		
Frequency range covered	7145–7235 MHz	S-Band downlink is not available with X-Band uplink because S/X Dichroic Plate will not pass X-Band uplink frequencies
Coherent with deep space X-Band D/L channels	7149.6–7188.9 MHz	880/749 turnaround ratio
Coherent with deep space Ka-Band D/L allocation	7149.6–7234.6 MHz	3344/749 turnaround ratio. Note: X-Band uplink frequencies greater than 7190 MHz are outside deep space X-Band uplink allocation.

Table 4. X-Band Transmit Characteristics, DSS 24, 25, 26, 34, 54, and 55 (Continued)

Parameter	Value	Remarks
EXCITER AND TRANSMITTER (Continued)		
RF Power Output		Referenced to 20-kW transmitter output terminal (waterload switch). Settability is limited to 0.25 dB by measurement equipment precision.
7145.0–7190.0 MHz	53.0–73.0 ±0.5 dBm	Deep space uplink allocation
7190.0–7235.0 MHz	53.0–67.6 ±0.5 dBm	Earth orbiter uplink allocation
Power output varies across the bandwidth and may be as much as 1 dB below nominal rating. Performance will also vary from tube to tube. Normal procedure is to run the tubes saturated, but unsaturated operation is also possible. The point at which saturation is achieved depends on drive power and beam voltage. The 20-kW tubes are normally saturated for power levels greater than 60 dBm (1 kW). Minimum power out of the 20-kW tubes is about 53 dBm (200 W). Efficiency of the tubes drops off rapidly below nominal rated output.		
EIRP (maximum)		At gain set elevation angle, referenced to feedhorn aperture
DSS 24, 25		
7145.0–7190.0 MHz	139.7 ±0.7 dBm	Deep space allocation
7190.0–7235.0 MHz	134.3 ±0.7 dBm	Earth orbiter allocation
DSS 26, 34, 54, 55		
7145.0–7190.0 MHz	139.5 ±0.7 dBm	Deep space allocation
7190.0–7235.0 MHz	134.1 ±0.7 dBm	Earth orbiter allocation
Tunability		At transmitter output frequency
Phase Continuous Tuning Range	2.0 MHz	
Maximum Tuning Rate	±12.1 kHz/s	
Frequency Error	0.012 Hz	Average over 100 ms with respect to frequency specified by predicts
Ramp Rate Error	0.001 Hz	Average over 4.5 s with respect to rate calculated from frequency predicts

Table 4. X-Band Transmit Characteristics, DSS 24, 25, 26, 34, 54, and 55 (Continued)

Parameter	Value	Remarks
EXCITER AND TRANSMITTER (Continued)		
Stability		At transmitter output frequency
Output Power Stability		From initial calibration value over 8 hours at a fixed frequency
Saturated Drive	±0.3 dB peak	
Unsaturated Drive	±0.5 dB peak	
Output Power Variation		Across any 2 MHz segment
Saturated Drive	≤0.3 dB p-p	
Unsaturated Drive	≤0.5 dB p-p	
Group Delay Stability	≤ 1.5 ns rms	Ranging modulation signal path over 8 h period (see module 203)
Spurious Output		Below carrier
1–10 Hz	–50 dB	
10 Hz–1.5 MHz	–60 dB	
1.5 MHz–8 MHz	–45 dB	
2nd Harmonic	–75 dB	
3rd, 4th & 5th Harmonics	–60 dB	

Table 5. Ka-Band Transmit Characteristics, DSS 25

Parameter	Value	Remarks
ANTENNA		
Gain at 34300 MHz		At peak of gain versus elevation angle curve, referenced to feedhorn aperture for matched polarization; no atmosphere included; triangular PDF tolerance.
Ka-only mode	79.52 +0.2 –0.3 dBi	
X/Ka-mode	79.37 +0.2 –0.3 dBi	
Transmitter Waveguide Loss	0.25 ±0.1 dB	800W transmitter output terminal (waterload switch) to feedhorn aperture
Half-Power Beamwidth	0.016 ±0.001 deg	Angular width (2-sided) between half-power points at specified frequency
Polarization	LCP	RCP is available by changing mechanical configuration of feed
Ellipticity	1.0 dB (max)	Peak-to-peak axial ratio. See Table 2 for definition.
Pointing Loss	0.12 dB	Monopulse aided tracking with minimum required signal level
Angular	See module 302	See also Figures 36 and 37
EXCITER AND TRANSMITTER		
Frequency range covered		
Exciter	34200-34700 MHz	
Transmitter	34315-34415 MHz	Bandwidth is limited by narrow band klystron
Coherent with deep space Ka-Band D/L channels	34317.8-34406.3 MHz	3360/3599 turnaround ratio
Coherent with deep space X-Band D/L channels	34354.3-34409.8 MHz	880/3599 turnaround ratio

Table 5. Ka-Band Transmit Characteristics, DSS 25 (Continued)

Parameter	Value	Remarks
EXCITER AND TRANSMITTER (Continued)		
RF Power Output	47.0–59.0 ±0.5 dBm	Referenced to 800 W transmitter output terminal (transmitter RF drawer rear panel flange). Settability is limited to 0.25 dB by measurement equipment precision.
Power output varies across the bandwidth and may be as much as 1 dB below nominal rating. The 800 W tube is a fixed beam klystron. Minimum power output is about 47 dBm (50 W) and may operate unsaturated.		
EIRP (maximum)	138.22 +0.6,–0.5 dBm	At gain set elevation angle, referenced to feedhorn aperture
Output Power Variation	≤ ±1.0 dB	Across frequency band over 8 hours
Spurious Output		Below carrier
1–10 Hz	–50 dB	
10 Hz–1.5 MHz	–60 dB	
1.5 MHz–8 MHz	–45 dB	

Table 6. S- and K-Band Receive Characteristics, DSS 24, 34, and 54

Parameter	Value	Remarks
ANTENNA		
Gain		At peak of gain versus elevation angle curve, referenced to feedhorn aperture (feed and feedline losses are accounted for in system temperature), for matched polarization; no atmosphere included; triangular PDF tolerance. See Figures 6 and 13-15 for representative gain versus elevation curves.
S-band (2295 MHz)	56.84 +0.1,–0.2 dBi	
K-band (26000 MHz)	77.2 +0.0,–0.2 dBi	
Half-Power Beamwidth		Angular width (2-sided) between half-power points at specified frequency
S-band	0.242 ±0.020 deg	
K-band	0.021 ±0.002 deg	
Polarization	RCP or LCP	Remotely selected. S-band must be same as transmit polarization
Ellipticity	≤1.0 dB	Peak-to-peak voltage axial ratio, RCP and LCP. See definition in Table 2.
Pointing Loss		
Angular	See module 302	See also Figure 34.
CONSCAN	0.1 dB	Recommended value
S-BAND RECEIVER		
Frequency Range Covered	2200–2300 MHz	
Recommended Maximum Signal Power	-90.0 dBm	At LNA input terminal
Antenna-Microwave Noise Temperature (T_{AMW})		Near zenith, no atmosphere or cosmic noise included. See Table 11 for 25% CD average clear sky noise contribution. See Figures 20 and 27-29 for representative system temperature versus elevation curves. Favorable (–) and adverse (+) tolerances have triangular PDF.

Table 6. S- and K-Band Receive Characteristics, DSS 24, 34, and 54 (Continued)

Parameter	Value	Remarks
S-BAND RECEIVER (Continued)		
Non-Diplexed Path		Referenced to feedhorn aperture. LNA = HEMT-1
DSS 24	26.10 –1.0,+2.0 K	
DSS 34	24.88 –1.0,+2.0 K	
DSS 54	25.73 –1.0,+2.0 K	
Diplexed Path		Referenced to feedhorn aperture. LNA = HEMT-1
DSS 24	33.47 –1.0,+2.0 K	
DSS 34	34.46 –1.0,+2.0 K	
DSS 54	35.35 –1.0,+2.0 K	
Tunability	Continuous	
Carrier Tracking Loop Noise B/W (Hz)	0.25 – 200	Effective one-sided, noise-equivalent carrier loop bandwidth (B_L)
K-BAND RECEIVER		
Frequency Range Covered	25500–27000 MHz	
Recommended Maximum Signal Power		At LNA input terminal
Normal Mode	–75.0 dBm	
Low-gain Mode	–45.0 dBm	
Antenna-Microwave Noise Temperature (T_{AMW})		RCP/LCP average at 26000 MHz. Referenced to feedhorn aperture. See also Table 11.
DSS 24 K-only mode	26.7 –1.0,+3.0 K	
DSS 24 S/K-mode	32.2 –1.0,+3.0 K	
DSS 34 K-only mode	28.4 –1.0,+3.0 K	
DSS 34 S/K-mode	33.5 –1.0,+3.0 K	
DSS 54 K-only mode	27.9 –1.0,+3.0 K	
DSS 54 S/K-mode	33.2 –1.0,+3.0 K	

Table 6. S- and K-Band Receive Characteristics, DSS 24, 34, and 54 (Continued)

Parameter	Value	Remarks
K-BAND RECEIVER (Continued)		
Low Gain Mode		Required for signal levels in excess of –75.0 dBm
K-only (All Stations)	156 –11.0,+33.0 K	
S/K-only (All Stations	185 –11.0,+33.0 K	
Tunability	1 Hz resolution	
Carrier Tracking Loop Noise B/W	0.1% of symbol rate	Effective one-sided, noise-equivalent carrier loop bandwidth (B_L)
Symbol Loop Acquisition B/W	0.3% of symbol rate	

Table 7. X-Band Receive Characteristics, DSS 24

Parameter	Value	Remarks
MAIN ANTENNA		
Gain (8420 MHz)		At peak of gain versus elevation angle curve, referenced to feedhorn aperture (feed and feedline losses are accounted for in system temperature), for matched polarization; no atmosphere included; triangular PDF tolerance.
X-only Mode	68.24 +0.1,–0.2 dBi	
S/X Mode	68.19 +0.1,–0.2 dBi	
Half-Power Beamwidth	0.066 ±0.004 deg	Angular width (2-sided) between half-power points at specified frequency
Polarization	RCP or LCP	Remotely Selected. Same as or opposite from transmit polarization
Ellipticity	≤0.7 dB	Peak-to-peak voltage axial ratio, RCP and LCP. See definition in Table 2.
Pointing Loss		
Angular	See module 302	See also Figure 35.
CONSCAN	0.1 dB	Recommended value when using X-Band CONSCAN reference
RECEIVER		
Frequency Range Covered	8400–8500 MHz	
Recommended Maximum Signal Power	-90.0 dBm	At LNA input terminal
Antenna-Microwave Noise Temperature (T_{AMW})		Near zenith, no atmosphere or cosmic noise included. See Table 11 for 25% CD average clear sky noise contribution. Favorable (–) and adverse (+) tolerances have triangular PDF.
Non-Diplexed Path (8400–8500 MHz) LNA = MASER-1	21.28 –1.0,+2.0 K	X-Band-only operation (S/X-Band dichroic plate retracted). Referenced to feedhorn aperture.
Diplexed Path (8400–8500 MHz) LNA = MASER-1	30.39 –1.0,+2.0 K	X-Band-only operation (S/X-Band dichroic plate retracted). Referenced to feedhorn aperture...

Table 7. X-Band Receive Characteristics, DSS 24 (Continued)

Parameter	Value	Remarks
RECEIVER (Continued)		
Antenna-Microwave Noise Temperature (Continued)		
Non-Diplexed Path (8400–8500 MHz) LNA = MASER-1	22.72 –1.0,+2.0 K	S/X-Band operation (S/X-Band dichroic plate extended). Referenced to feedhorn aperture.
Diplexed Path (8400–8500 MHz) LNA = MASER-1	31.89 –1.0,+2.0 K	S/X-Band operation (S/X-Band dichroic plate extended). Referenced to feedhorn aperture.
Tunability	Continuous	
Carrier Tracking Loop Noise B/W (Hz)	0.25 – 200	Effective one-sided, noise-equivalent carrier loop bandwidth (B_L)
ACQUISITION ANTENNA AND RECEIVER		
Gain (8420 MHz)	38.0 ±0.5 dB	Referenced to acquisition downconverter input terminals (includes feedline losses)
Half-Power Beamwidth	2.1 deg	Angular width (2-sided) between half-power points at specified frequency
Polarization	RCP	LCP is available by manual selection at feed
Frequency Range Covered	8400–8500 MHz	
System Temperature	280 ±30K.	Near Zenith
Tracking Bandwidths		Two-sided bandwidths
Residual Carrier	4 kHz	
Frequency Acquisition	±150 kHz	
Doppler Tracking	±400 kHz	
Suppressed Carrier	280 kHz	Open-loop operation
Tunability	1 kHz resolution	
Signal Acquistion Range		
Residual Carrier	–90 to –135 dBm	
Suppressed Carrier	–90 to –119 dBm.	

Table 8. X- and Ka-Band Receive Characteristics, DSS 25, 26, 34, 54, and 55

Parameter	Value	Remarks
MAIN ANTENNA		
Gain		At peak of gain versus elevation angle curve, referenced to feedhorn aperture (feed and feedline losses are accounted for in system temperature), for matched polarization; no atmosphere included; triangular PDF tolerance. See Figures 8–12 and 16-19 for representative gain versus elevation curves.
X-Band (8420 MHz)	68.30 +0.1,–0.2 dBi	DSS 34 and 54, S/X-Band operation (S/X-Band dichroic plate extended). DSS 25, 26, and 55 do not have S-band capability.
X-Band (8420 MHz)	68.50 +0.1,–0.2 dBi	DSS 25, X/Ka-Band operation (X/Ka-Band dichroic plate extended).
	68.33 +0.1,–0.2 dBi	DSS 26, 34, 54, & 55, X/Ka-Band operation.
Ka-Band (32000 MHz)	79.00 +0.3,–0.3 dBi	DSS 25, Ka-Band only operation (X/Ka-Band dichroic plate retracted).
	78.85 +0.3,–0.3 dBi	DSS 25, X/Ka-Band operation (X/Ka-Band dichroic plate extended).
	79.13 +0.3,–0.3 dBi	DSS 26 and DSS 55 X/Ka-Band operation.
	78.98 +0.3,–0.3 dBi	DSS 34, X/Ka-Band operation.
	78.38 +0.3,–0.3 dBi	DSS 54, X/Ka-Band operation
Half-Power Beamwidth		Angular width (2-sided) between half-power points at specified frequency
X-Band	0.066 ±0.004 deg	
Ka-Band	0.017 ±0.002 deg	
Polarization		
X-Band DSS 25	RCP and LCP	Both polarizations simultaneously available; polarizations of diplexed and non-diplexed paths are remotely selected
X-Band DSS 26 and 55	RCP and LCP	Simultaneously
X-Band DSS 34 and 54	RCP or LCP	Remotely selected. Independent of transmit polarization.

Table 8. X- and Ka-Band Receive Characteristics, DSS 25, 26, 34, 54, and 55 (Continued)

Parameter	Value	Remarks
MAIN ANTENNA (Continued)		
Polarization (Continued)		
Ka-Band DSS 25	RCP	RCP monopulse is available.
Ka-Band DSS 26, 55	RCP and LCP	Monopulse only is available at RCP
Ka-Band DSS 34, 54	RCP or LCP	Monopulse only is available at RCP.
Ellipticity		Peak-to-peak voltage axial ratio. See definition in Table 2.
X-Band	≤0.7 dB	RCP and LCP.
Ka-Band	≤1.0 dB	
Pointing Loss		
Angular	See module 302	See also Figures 35 and 36.
CONSCAN		.
X-Band	0.1 dB	Recommended value when using X-Band CONSCAN reference
Ka-Band	N/A	Use of CONSCAN at Ka-Band is not recommended.
Monopulse		
X-Band	0.007 dB	Using Ka-Band monopulse reference
Ka-Band	0.11 dB	Sum channel signal to error channel noise ratio ≥ 26 dB-Hz
RECEIVER		
Frequency Ranges		
X-Band	8400–8500 MHz	
Ka-Band	31800–32300 MHz	Tracking receiver covers bandwidth with 5 overlapping bands of ≈ 160 MHz
Recommended Maximum Signal Power	–90.0 dBm	At LNA input terminal

Table 8. X- and Ka-Band Receive Characteristics, DSS 25, 26, 34, 54, and 55 (Continued)

Parameter	Value	Remarks
RECEIVER (Continued)		
Antenna-Microwave Noise Temperature (T_{AMW})		Near zenith, no atmosphere or cosmic noise included. See Table 11 for 25% CD average clear sky noise contribution. See Figures 22-26 and 30-33 for representative system temperature versus elevation curves. Favorable (–) and adverse (+) tolerances have triangular PDF.
X-Band (8400–8500 MHz)		Non-diplexed path, referenced to feedhorn aperture.
DSS 25, MASER	20.20 –1.0,+2.0 K	RCP or LCP
DSS 25, HEMT	35.06 –1.0,+2.0 K	RCP or LCP
X-Band (8400–8500 MHz)		Diplexed path, referenced to feedhorn aperture.
DSS 25, MASER	29.26 –1.0,+2.0 K	RCP or LCP
DSS 25, HEMT	44.88 –1.0,+2.0 K	RCP or LCP
X-Band (8400–8500 MHz)		Feed diplexed, with or without transmitter operating. Referenced to feedhorn aperture.
DSS 26 (RCP)	16.29 –1.0,+2.0 K	LNA = HEMT-1
DSS 26 (LCP)	15.43 –1.0,+2.0 K	LNA = HEMT-2
DSS 34 (RCP)	16.28 –1.0,+2.0 K	X/Ka operation, LNA = HEMT-1
DSS 34 (LCP)	16.71 –1.0,+2.0 K	X/Ka operation, LNA = HEMT-2
DSS 34 (RCP)	17.99 –1.0,+2.0 K	S/X operation, LNA = HEMT-1
DSS 34 (LCP)	18.43 –1.0,+2.0 K	S/X operation, LNA = HEMT-2
DSS 54 (RCP)	18.31 –1.0,+2.0 K	X/Ka operation, LNA = HEMT-1
DSS 54 (LCP)	18.31 –1.0,+2.0 K	X/Ka operation, LNA = HEMT-2
DSS 54 (RCP)	20.03 –1.0,+2.0 K	S/X operation, LNA = HEMT-1
DSS 54 (LCP)	20.03 –1.0,+2.0 K	S/X operation, LNA = HEMT-2
DSS 55 (RCP)	17.42 –1.0,+2.0 K	LNA = HEMT-1
DSS 55 (LCP)	17.82 –1.0,+2.0 K	LNA = HEMT-2

Table 8. X- and Ka-Band Receive Characteristics, DSS 25, 26, 34, 54, and 55 (Continued)

Parameter	Value	Remarks
RECEIVER (Continued)		
Antenna-Microwave Noise Temperature (T_{AMW}) (Continued)		
Ka-Band (31800–32300 MHz)		Ka-Band only operation (X/Ka-Band dichroic plate at DSS 25 retracted), referenced to feedhorn aperture,
DSS 25 (RCP)	27.89 –1.0,+2.0 K	LNA = HEMT-1
DSS 25 (RCP Error)	27.30 –1.0,+2.0 K	LNA = HEMT-2
Ka-Band (31800–32300 MHz)		X/Ka-Band operation (X/Ka-Band dichroic plate at DSS 25 extended), referenced to feedhorn aperture,
DSS 25 (RCP)	31.41 –1.0,+2.0 K	LNA = HEMT-1
DSS 25 (RCP Error)	35.53 –1.0,+2.0 K	LNA = HEMT-2
Ka-Band (31800–32300 MHz)		X/Ka-Band operation referenced to feedhorn aperture,
DSS 26 (RCP)	19.36 –1.0,+2.0 K	LNA = HEMT-1
DSS 26 (RCP Error)	24.55 –1.0,+2.0 K	LNA = HEMT-2
DSS 26 (LCP)	20.77 –1.0,+2.0 K	LNA = HEMT-3
DSS 34 (RCP)	19.38 –1.0,+2.0 K	LNA = HEMT-1
DSS 34 (RCP Error)	23.25 –1.0,+2.0 K	LNA = HEMT-2
DSS 34 (LCP)	19.61 –1.0,+2.0 K	LNA = HEMT-3
DSS 54 (RCP)	21.80 –1.0,+2.0 K	LNA = HEMT-1
DSS 54 (RCP Error)	25.00 –1.0,+2.0 K	LNA = HEMT-2
DSS 54 (LCP)	21.80 –1.0,+2.0 K	LNA = HEMT-3
DSS 55 (RCP)	20.80 –1.0,+2.0 K	LNA = HEMT-1
DSS 55 (RCP Error)	21.98 –1.0,+2.0 K	LNA = HEMT-2
DSS 55 (LCP)	19.83 –1.0,+2.0 K	LNA = HEMT-3
Carrier Tracking Loop Noise B/W	0.25 – 200 Hz	Effective one-sided, noise-equivalent carrier loop bandwidth (B_L). See module 202

Table 8. X- and Ka-Band Receive Characteristics, DSS 25, 26, 34, 54, and 55 (Continued)

Parameter	Value	Remarks
ACQUISITION ANTENNA AND RECEIVER		
Gain (8420 MHz)	38.0 ±0.5 dB	Referenced to acquisition downconverter input terminals (includes feedline losses)
Half-Power Beamwidth	2.1 deg	Angular width (2-sided) between half-power points at specified frequency
Polarization	RCP	LCP is available by manual selection at feed
Frequency Range Covered	8400–8500 MHz	
System Temperature	280 ±30K.	Near Zenith
Tracking Bandwidths		Two-sided bandwidths
Residual Carrier	4 kHz	
Frequency Acquisition	±150 kHz	
Doppler Tracking	±400 kHz	
Suppressed Carrier	280 kHz	Open-loop operation
Tunability	1 kHz resolution	
Signal Acquistion Range		
Residual Carrier	–90 to –135 dBm	
Suppressed Carrier	–90 to –119 dBm.	

Table 9. S-Band Receive Characteristics, DSS 27

Parameter	Value	Remarks
ANTENNA		
Gain (2250 MHz)		At peak of gain versus elevation angle curve, referenced to feedhorn aperture (feed and feedline losses are accounted for in system temperature), for matched polarization; no atmosphere included; triangular PDF tolerance. See Figure 7 for elevation dependency.
S-Band	55.04 +0.1,–0.2 dBi	
Half-Power Beamwidth		Angular width (2-sided) between half-power points at specified frequency
S-Band	0.247 ±0.020 dB	
Polarization		Remotely selected
S-Band	RCP or LCP	Same as transmit polarization
Ellipticity		Peak-to-peak voltage axial ratio, RCP and LCP. See definition in Table 2.
S-Band	≤1.0 dB	
Pointing Loss		
Angular	See module 302	See also Figure 34
RECEIVER		
Frequency Range Covered	2200–2300 MHz	S-Band
Recommended Maximum Signal Power	–90.0 dBm	At LNA input terminal
Antenna-Microwave Noise Temperature (T_{AMW})	102 –1.0,+2.0 K	With respect to feedhorn aperture, near zenith, no atmosphere or cosmic noise included. See Figure 21 for elevation dependency. Tolerances have a triangular PDF. LNA = Room temperature HEMT
Carrier Tracking Loop Noise B/W	0.25 – 200 Hz	Effective one-sided, noise-equivalent carrier loop bandwidth (B_L) when using standard DSN receiver. See module 202. Bandwidths less than 1 Hz are not recommended due to frequency reference instability.

Table 10. Gain Reduction Due to Wind Loading, 34-m BWG Antennas

Wind Speed		Gain Reduction (dB)*	
(km/hr)	**(mph)**	**X-Band**	**Ka-Band**
16	10	0.2	2.9
48	30	0.3	4.3
72	45	0.4	5.8

* Assumes antenna is maintained on-point using CONSCAN at X-Band or monopulse at Ka-Band. S-Band gain reduction is negligible for wind speeds up to 72 km/h (45 mph). Worst case with antenna in most adverse orientation for wind.

Table 11. T_{AMW}, T_{sky}, and T_{op} for CD=25% Average Clear Weather at Zenith, Referenced to Feedhorn Aperture

Frequency, Station, and Configuration	Noise Temperatures, K		
	T_{AMW}	T_{sky}	T_{op}
S-band, DSS 24, S/X, HEMT-1, RCP or LCP, non-diplexed	26.10	4.68	30.78
S-band, DSS 24, S/X, HEMT-1, RCP or LCP, diplexed	33.47	4.68	38.15
S-band, DSS 27, S-only, R/T HEMT-1, RCP or LCP, diplexed	101.79	4.68	106.47
S-band, DSS 34, S/X, HEMT-1, RCP or LCP, non-diplexed	24.88	4.86	29.74
S-band, DSS 34, S/X, HEMT-1, RCP or LCP, diplexed	34.46	4.86	39.32
S-band, DSS 54, S/X, HEMT-1, RCP or LCP, non-diplexed	25.73	4.80	30.53
S-band, DSS 54, S/X, HEMT-1, RCP or LCP, diplexed	35.35	4.80	40.15
X-band, DSS 24, X-only, MASER-1, RCP or LCP, non-diplexed	21.28	5.04	26.32
X-band, DSS 24, X-only, MASER-1, RCP or LCP, diplexed	30.39	5.04	35.43
X-band, DSS 24, S/X, MASER-1, RCP or LCP, non-diplexed	22.72	5.04	27.76
X-band, DSS 24, S/X, MASER-1, RCP or LCP, diplexed	31.89	5.04	36.93
X-band, DSS 25, X/Ka, MASER-1, RCP or LCP, non-diplexed	20.20	5.04	25.24
X-band, DSS 25, X/Ka, HEMT-1, RCP or LCP, non-diplexed	35.06	5.04	40.10
X-band, DSS 25, X/Ka, MASER-1, RCP or LCP, diplexed	29.26	5.04	34.30
X-band, DSS 25, X/Ka, HEMT-1, RCP or LCP, diplexed	44.88	5.04	49.92

Table 11. T_{AMW}, T_{sky}, and T_{op} for CD=25% Average Clear Weather at Zenith, Referenced to Feedhorn Aperture (Continued)

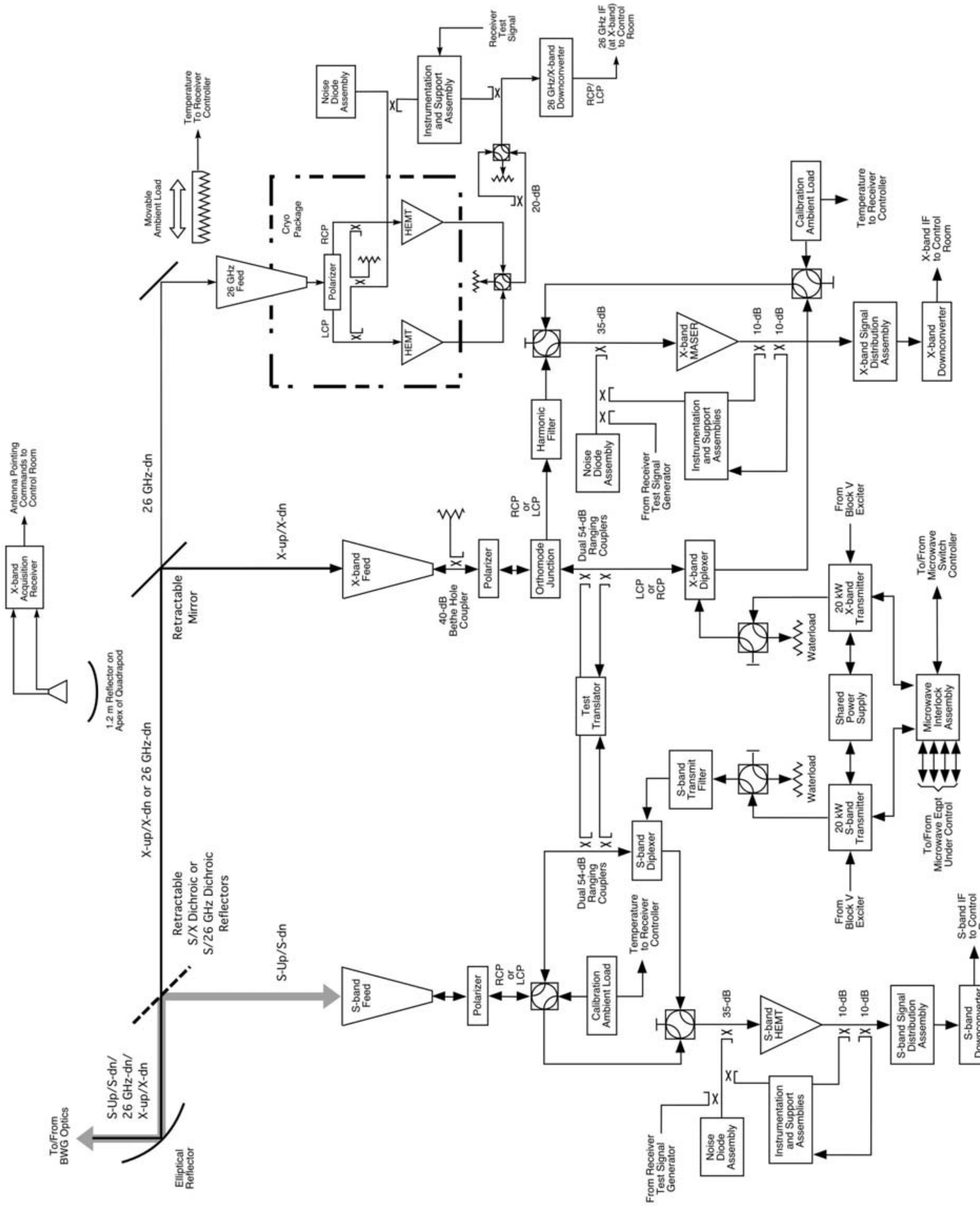
Frequency, Station, and Configuration	Noise Temperatures, K		
	T_{AMW}	T_{sky}	T_{op}
X-band, DSS 26, X/Ka, HEMT-1, RCP, diplexed	16.29	5.04	21.33
X-band, DSS 26, X/Ka, HEMT-2, LCP, diplexed	15.43	5.04	20.47
X-band, DSS 34, X/Ka, HEMT-1, RCP, diplexed	16.28	5.39	21.67
X-band, DSS 34, X/Ka, HEMT-2, LCP, diplexed	16.71	5.39	22.10
X-band, DSS 34, S/X, HEMT-1, RCP, diplexed	17.99	5.39	23.38
X-band, DSS 34, S/X, HEMT-2, LCP, diplexed	18.43	5.39	23.82
X-band, DSS 54, X/Ka, HEMT-1, RCP, diplexed	18.31	5.27	23.58
X-band, DSS 54, X/Ka, HEMT-2, LCP, diplexed	18.31	5.27	23.58
X-band, DSS 54, S/X, HEMT-1, RCP, diplexed	20.03	5.27	25.30
X-band, DSS 54, S/X, HEMT-2, LCP, diplexed	20.03	5.27	25.30
X-band, DSS 55, X/Ka, HEMT-1, RCP, diplexed	17.42	5.27	22.69
X-band, DSS 55, X/Ka, HEMT-2, LCP, diplexed	17.82	5.27	23.09
K-band, DSS 24, K-only, RCP, non-diplexed, 25.5 GHz	24.89	10.18	35.07
K-band, DSS 24, K-only, LCP, non-diplexed, 25.5 GHz	30.42	10.18	40.60
K-band, DSS 24, S/K, RCP, non-diplexed, 25.5 GHz	35.19	10.18	45.37
K-band, DSS 24, S/K, LCP, non-diplexed, 25.5 GHz	40.69	10.18	50.87
K-band, DSS 24, K-only, RCP, non-diplexed, 26.0 GHz	24.11	10.04	34.15
K-band, DSS 24, K-only, LCP, non-diplexed, 26.0 GHz	29.19	10.04	39.23
K-band, DSS 24, S/K, RCP, non-diplexed, 26.0 GHz	29.92	10.04	39.96
K-band, DSS 24, S/K, LCP, non-diplexed, 26.0 GHz	34.52	10.04	44.56
K-band, DSS 24, K-only, RCP, non-diplexed, 27.0 GHz	23.86	9.98	33.84
K-band, DSS 24, K-only, LCP, non-diplexed, 27.0 GHz	28.07	9.98	38.05
K-band, DSS 24, S/K, RCP, non-diplexed, 27.0 GHz	33.15	9.98	43.13
K-band, DSS 24, S/K, LCP, non-diplexed, 27.0 GHz	37.35	9.98	47.33

Table 11. T_{AMW}, T_{sky}, and T_{op} for CD=25% Average Clear Weather at Zenith, Referenced to Feedhorn Aperture (Continued)

Frequency, Station, and Configuration	Noise Temperatures, K		
	T_{AMW}	T_{sky}	T_{op}
K-band, DSS 34, K-only, RCP, non-diplexed, 25.5 GHz	26.31	13.40	39.71
K-band, DSS 34, K-only, LCP, non-diplexed, 25.5 GHz	27.49	13.40	40.89
K-band, DSS 34, S/K, RCP, non-diplexed, 25.5 GHz	37.17	13.40	50.57
K-band, DSS 34, S/K, LCP, non-diplexed, 25.5 GHz	37.29	13.40	50.69
K-band, DSS 34, K-only, RCP, non-diplexed, 26.0 GHz	27.89	13.11	41.00
K-band, DSS 34, K-only, LCP, non-diplexed, 26.0 GHz	28.81	13.11	41.92
K-band, DSS 34, S/K, RCP, non-diplexed, 26.0 GHz	33.01	13.11	46.12
K-band, DSS 34, S/K, LCP, non-diplexed, 26.0 GHz	33.91	13.11	47.02
K-band, DSS 34, K-only, RCP, non-diplexed, 27.0 GHz	24.10	12.87	36.97
K-band, DSS 34, K-only, LCP, non-diplexed, 27.0 GHz	24.89	12.87	37.76
K-band, DSS 34, S/K, RCP, non-diplexed, 27.0 GHz	34.87	12.87	47.74
K-band, DSS 34, S/K, LCP, non-diplexed, 27.0 GHz	34.45	12.87	47.32
K-band, DSS 54, K-only, RCP, non-diplexed, 25.5 GHz	27.86	11.92	39.78
K-band, DSS 54, K-only, LCP, non-diplexed, 25.5 GHz	26.26	11.92	38.18
K-band, DSS 54, S/K, RCP, non-diplexed, 25.5 GHz	38.44	11.92	50.36
K-band, DSS 54, S/K, LCP, non-diplexed, 25.5 GHz	36.29	11.92	48.21
K-band, DSS 54, K-only, RCP, non-diplexed, 26.0 GHz	28.01	11.71	39.72
K-band, DSS 54, K-only, LCP, non-diplexed, 26.0 GHz	27.75	11.71	39.46
K-band, DSS 54, S/K, RCP, non-diplexed, 26.0 GHz	33.47	11.71	45.18
K-band, DSS 54, S/K, LCP, non-diplexed, 26.0 GHz	32.97	11.71	44.68
K-band, DSS 54, K-only, RCP, non-diplexed, 27.0 GHz	25.27	11.55	36.82
K-band, DSS 54, K-only, LCP, non-diplexed, 27.0 GHz	24.22	11.55	35.77
K-band, DSS 54, S/K, RCP, non-diplexed, 27.0 GHz	35.30	11.55	46.85
K-band, DSS 54, S/K, LCP, non-diplexed, 27.0 GHz	33.63	11.55	45.18

Table 11. T_{AMW}, T_{sky}, and T_{op} for CD=25% Average Clear Weather at Zenith, Referenced to Feedhorn Aperture (Continued)

Frequency, Station, and Configuration	Noise Temperatures, K		
	T_{AMW}	T_{sky}	T_{op}
Ka-band, DSS 25, Ka-only, HEMT-1, RCP, diplexed	27.89	11.73	39.62
Ka-band, DSS 25, Ka-only, HEMT-2, RCP-error, diplexed	27.30	11.73	39.03
Ka-band, DSS 25, X/Ka, HEMT-1, RCP, diplexed	31.41	11.73	43.14
Ka-band, DSS 25, X/Ka, HEMT-2, RCP-error, diplexed	35.53	11.73	47.26
Ka-band, DSS 26, X/Ka, HEMT-1, RCP, non-diplexed	19.36	11.73	31.09
Ka-band, DSS 26, X/Ka, HEMT-2, RCP-error, non-diplexed	24.55	11.73	36.28
Ka-band, DSS 26, X/Ka, HEMT-3, LCP, non-diplexed	20.77	11.73	32.50
Ka-band, DSS 34, X/Ka, HEMT-1, RCP, non-diplexed	19.38	14.81	34.19
Ka-band, DSS 34, X/Ka, HEMT-2, RCP-error, non-diplexed	23.25	14.81	38.06
Ka-band, DSS 34, X/Ka, HEMT-3, LCP, non-diplexed	19.61	14.81	34.42
Ka-band, DSS 54, X/Ka, HEMT-1, RCP, non-diplexed	21.80	13.39	35.19
Ka-band, DSS 54, X/Ka, HEMT-2, RCP-error, non-diplexed	25.00	13.39	38.39
Ka-band, DSS 54, X/Ka, HEMT-3, LCP, non-diplexed	21.80	13.39	35.19
Ka-band, DSS 55, X/Ka, HEMT-1, RCP, non-diplexed	20.80	13.39	34.19
Ka-band, DSS 55, X/Ka, HEMT-2, RCP-error, non-diplexed	21.98	13.39	35.37
Ka-band, DSS 55, X/Ka, HEMT-3, LCP, non-diplexed	19.83	13.39	33.22



NOTE: X-band uplink is not available when S-band downlink is required (S/X Dichroic in place).

Figure 1. Functional Block Diagram of the DSS 24 Antenna

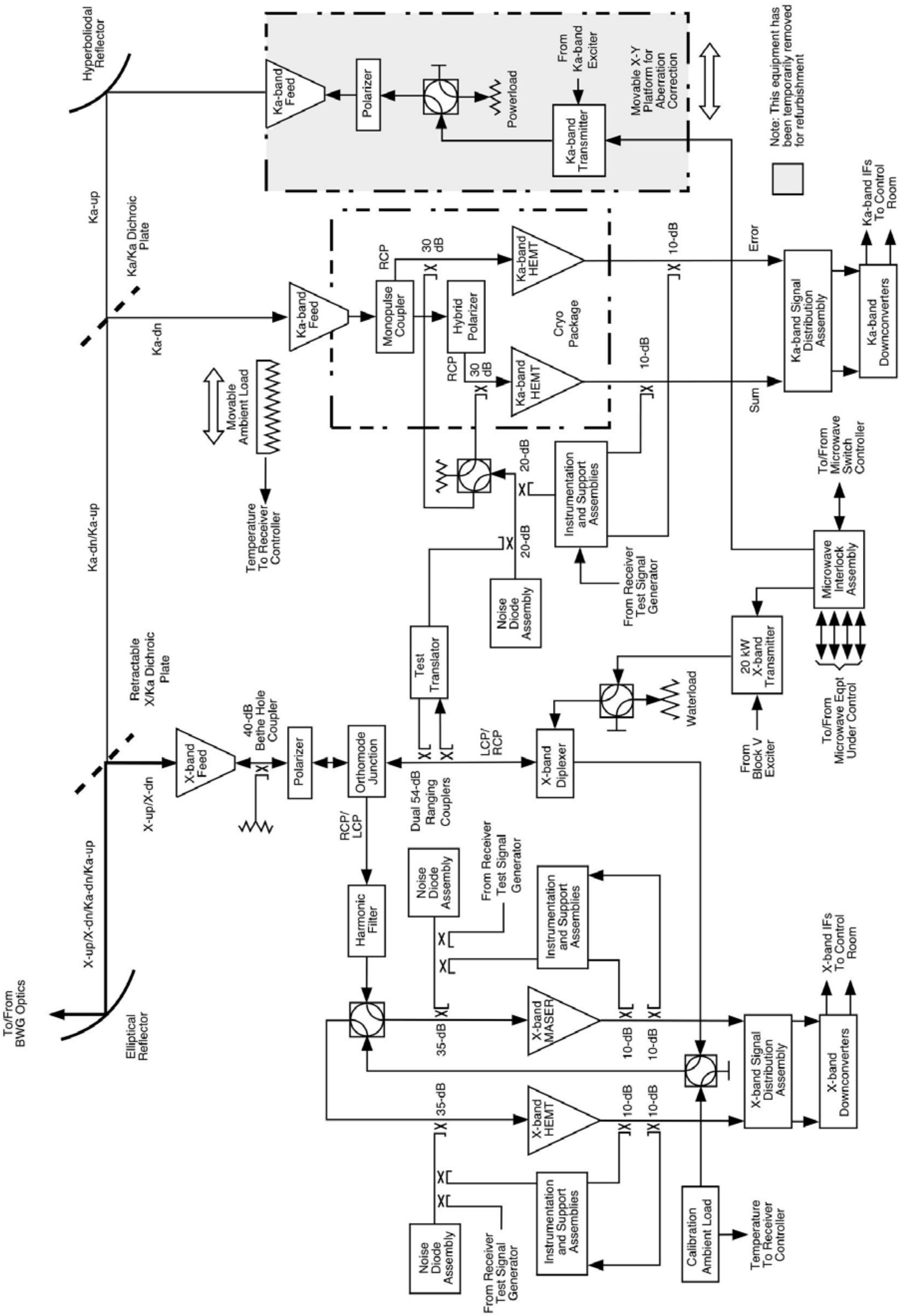


Figure 2. Functional Block Diagram of the DSS 25 Antenna.

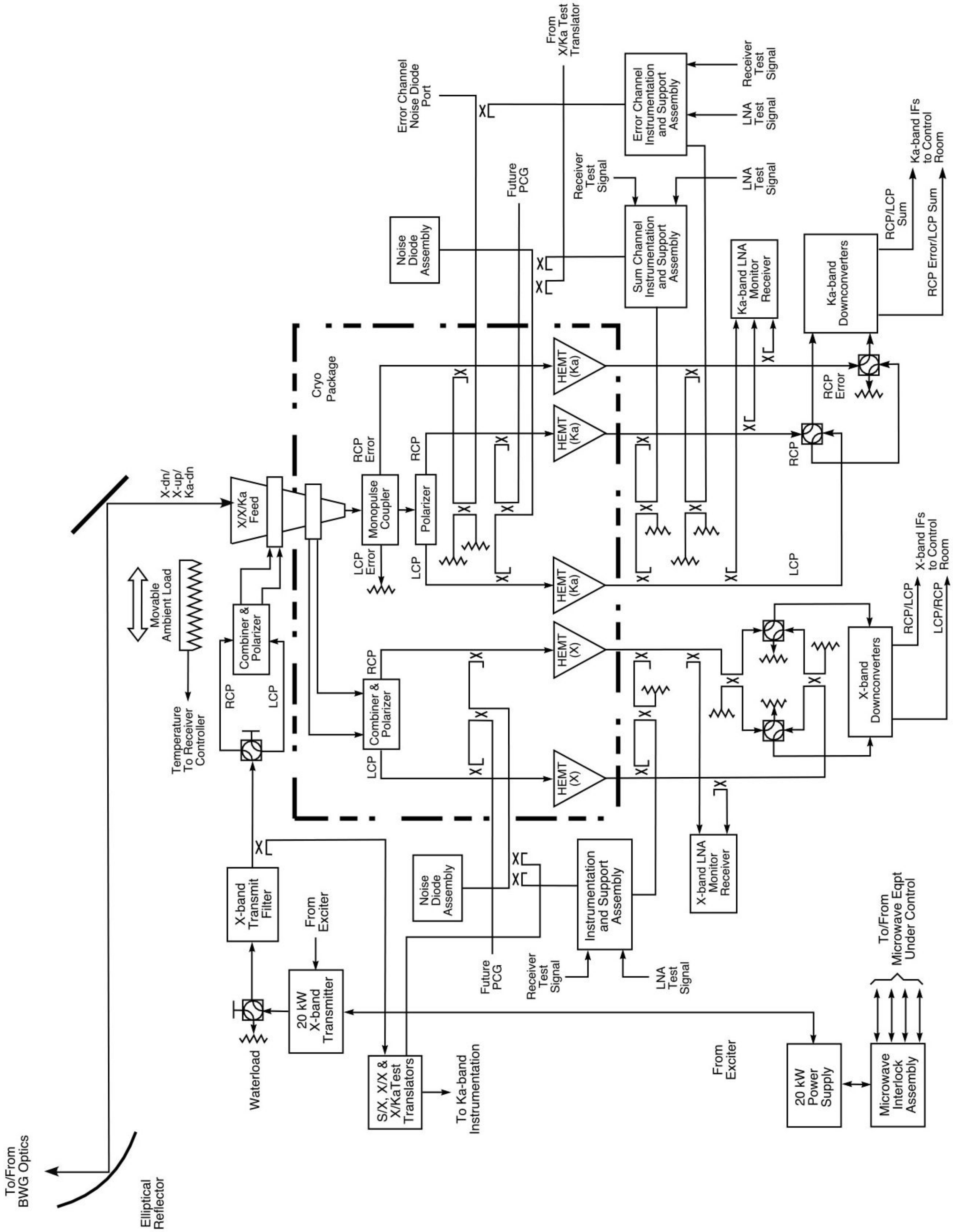
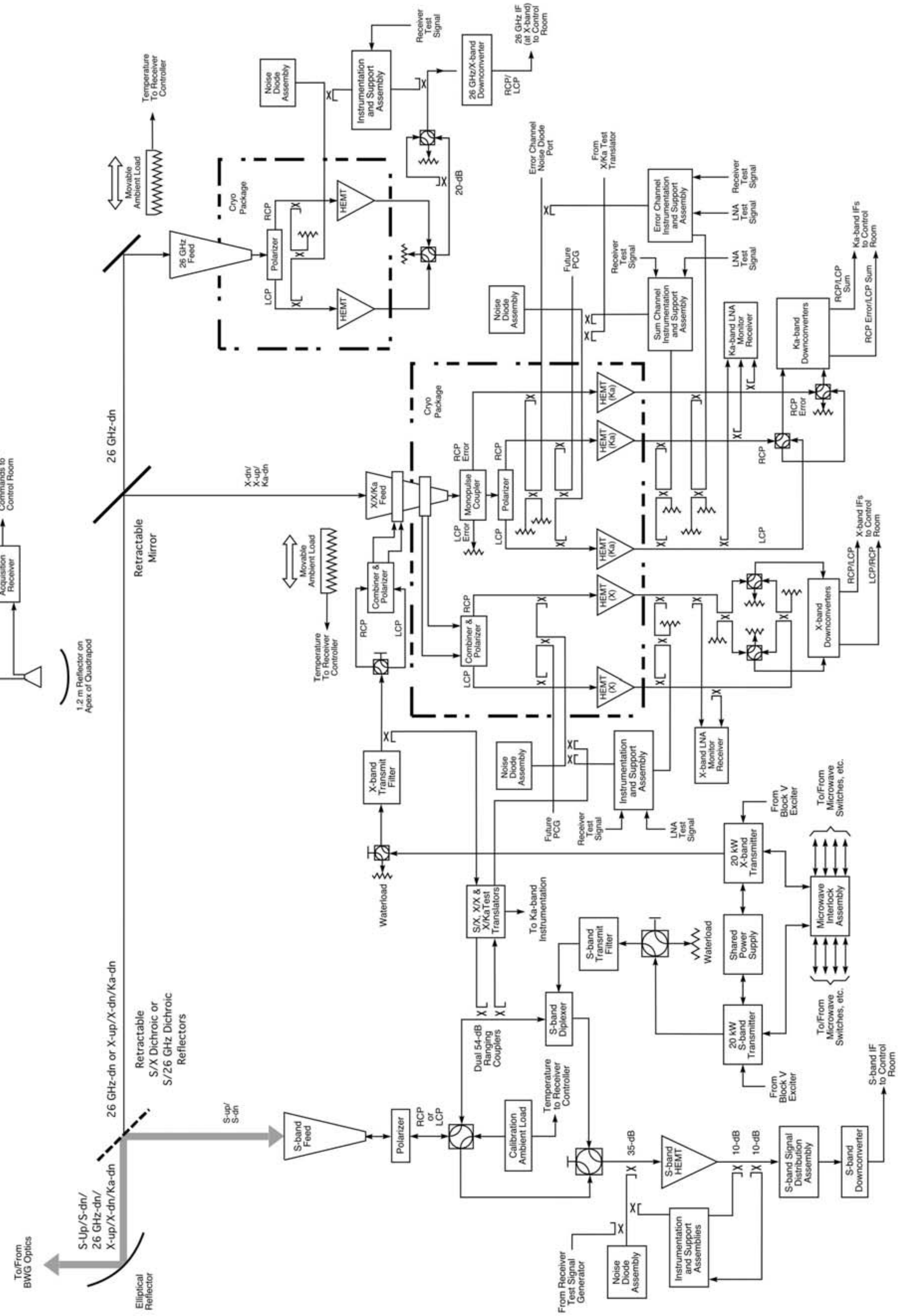


Figure 3. Functional Block Diagram of the DSS 26 and DSS 55 Antennas



NOTE: X-band uplink is not available when S-band downlink is required (S/X Dichroic in place).

Figure 4. Functional Block Diagram of the DSS 34 and DSS 54 Antennas

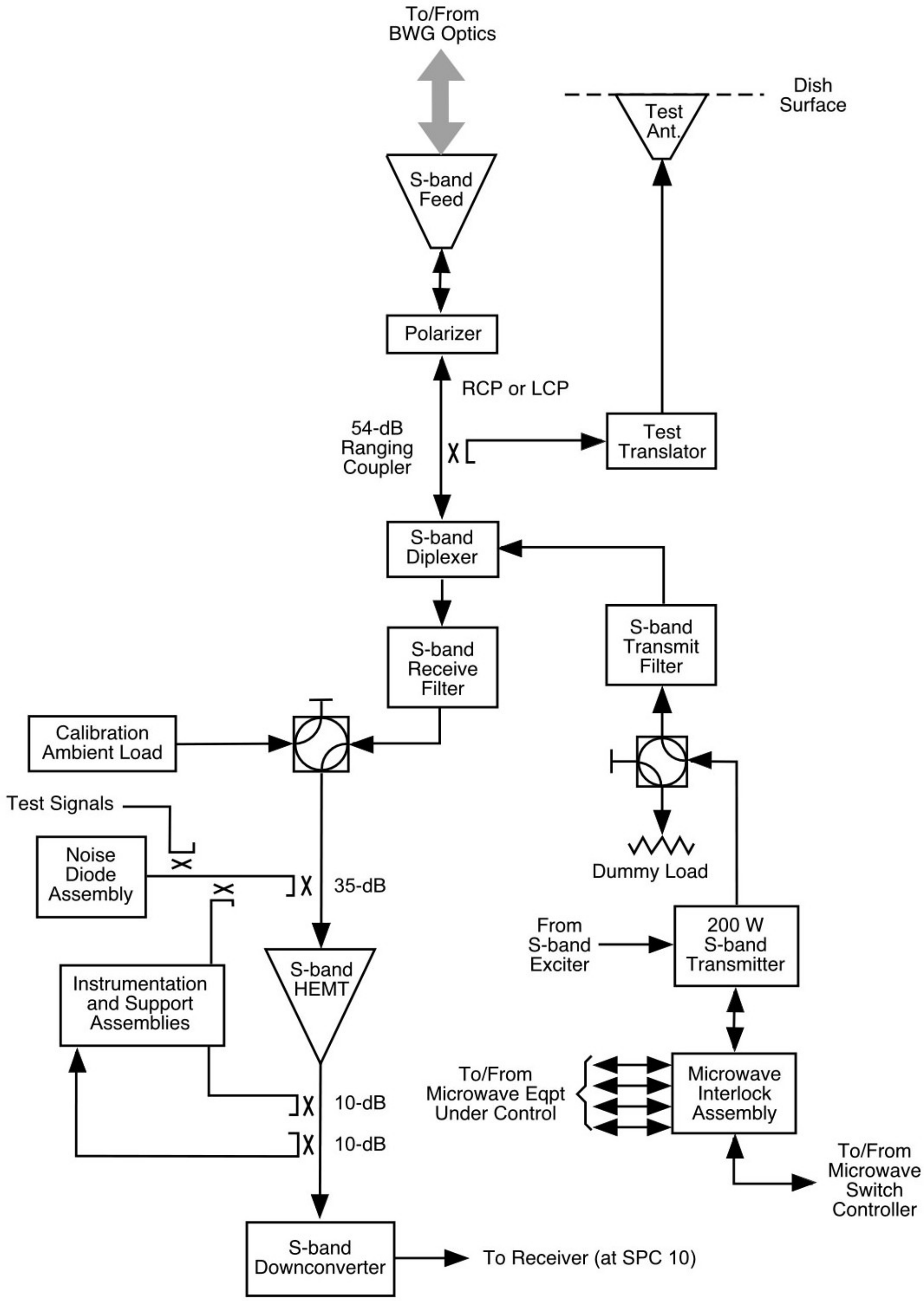


Figure 5. Functional Block Diagram of the DSS 27 Antenna

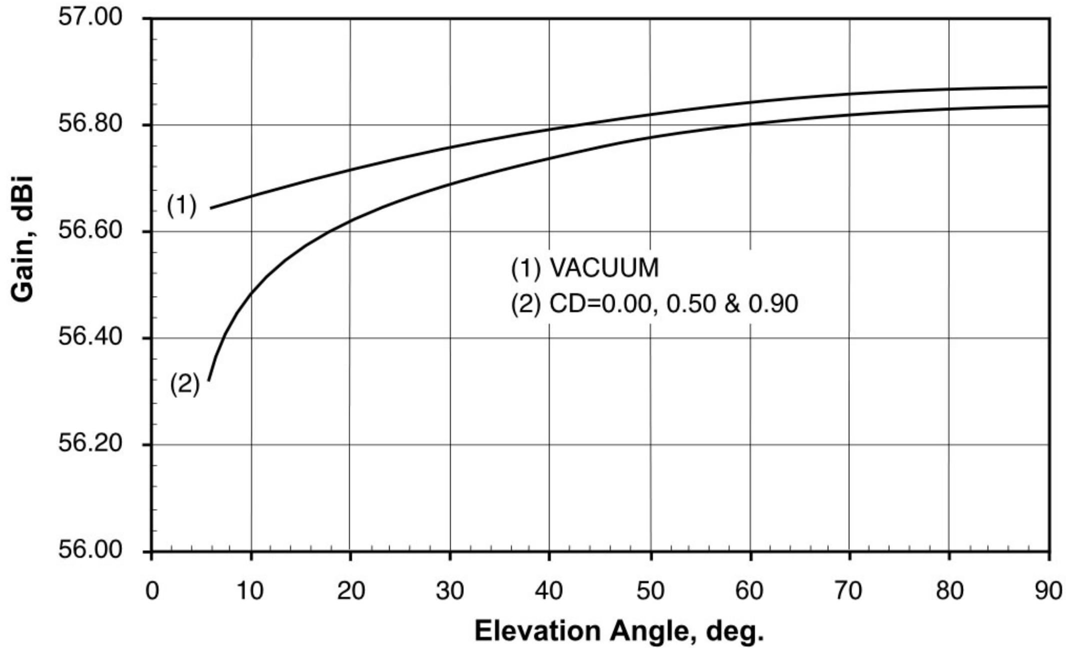


Figure 6. DSS 24 (Goldstone) S-Band Receive Gain versus Elevation Angle, S/X Mode (S/X Dichroic In Place), 2295 MHz

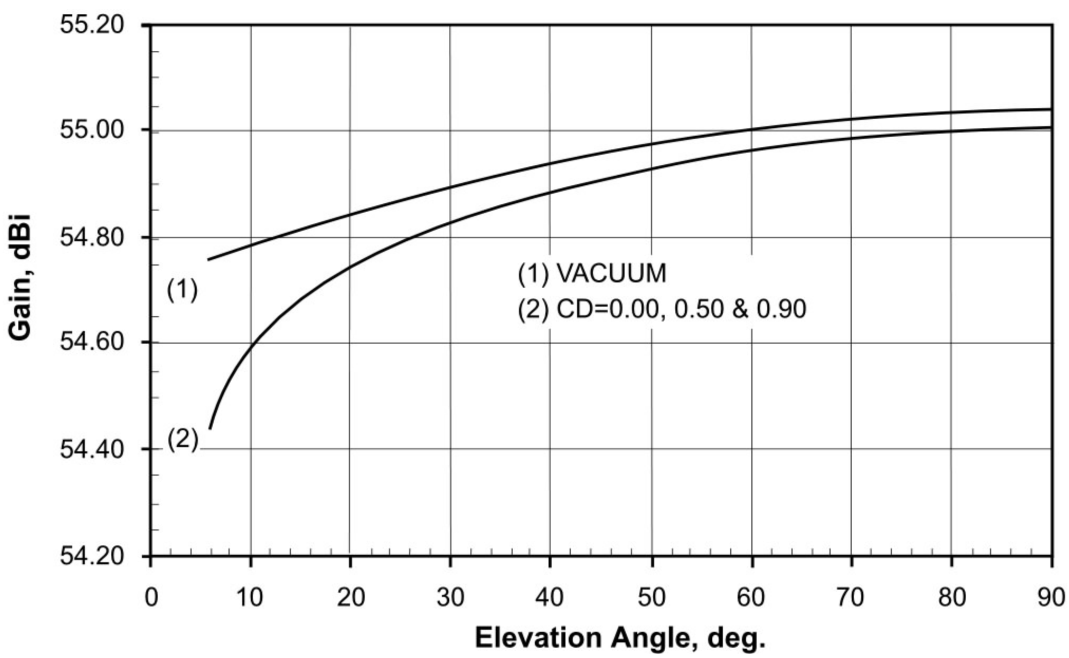


Figure 7. DSS 27 (Goldstone) S-Band Receive Gain versus Elevation Angle, 2250 MHz

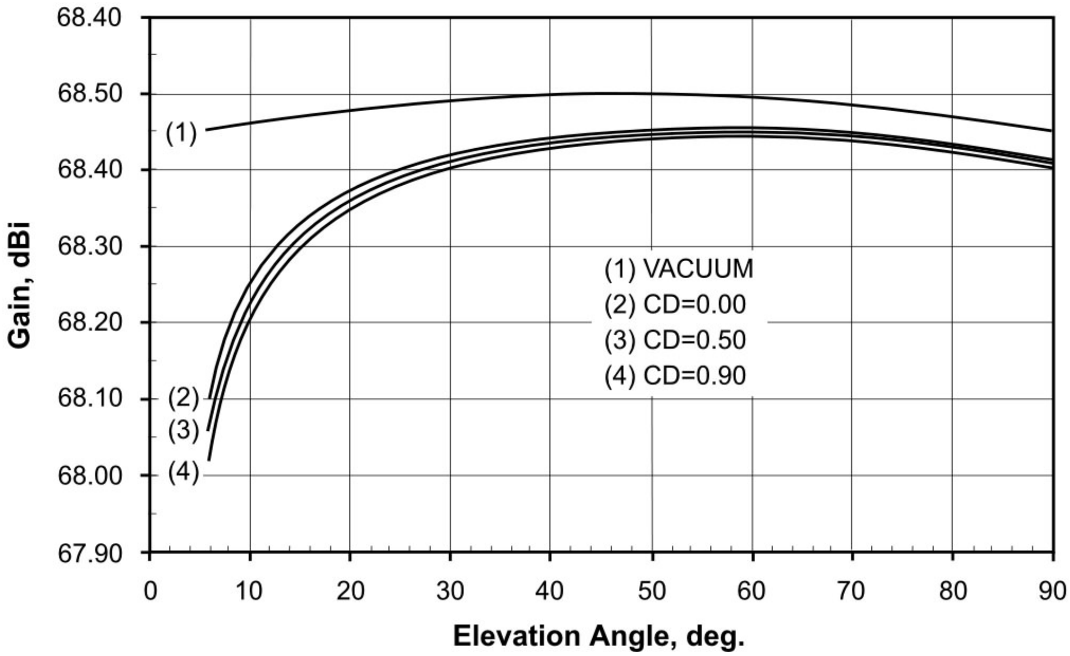


Figure 8. DSS 25 (Goldstone) X-Band Receive Gain versus Elevation Angle, X/Ka Mode (X/Ka Dichroic In Place), 8420 MHz

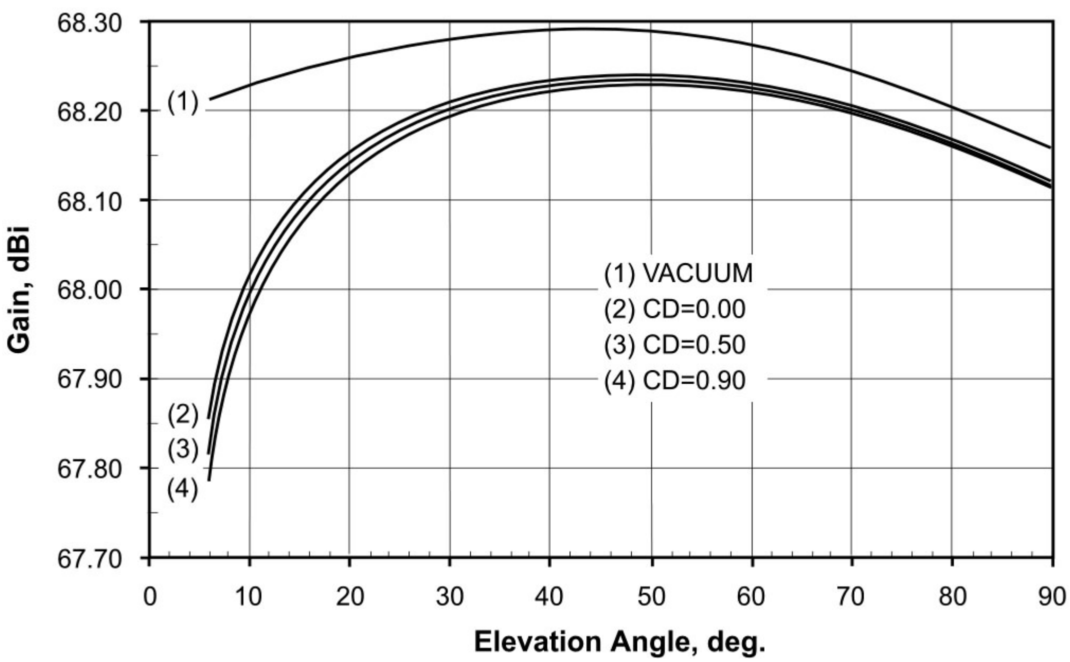


Figure 9. DSS 26 (Goldstone) X-Band Receive Gain versus Elevation Angle, X/Ka-Mode, 8420 MHz

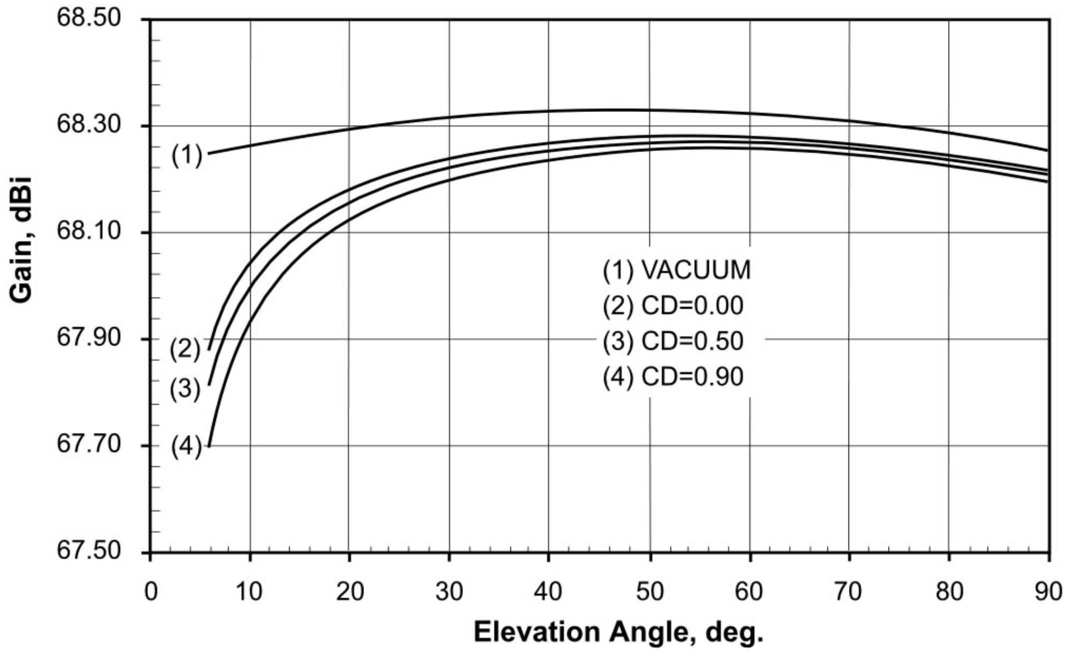


Figure 10. DSS 34 (Canberra) X-Band Receive Gain versus Elevation Angle, X/Ka-Mode (S/X Dichroic Retracted), 8420 MHz

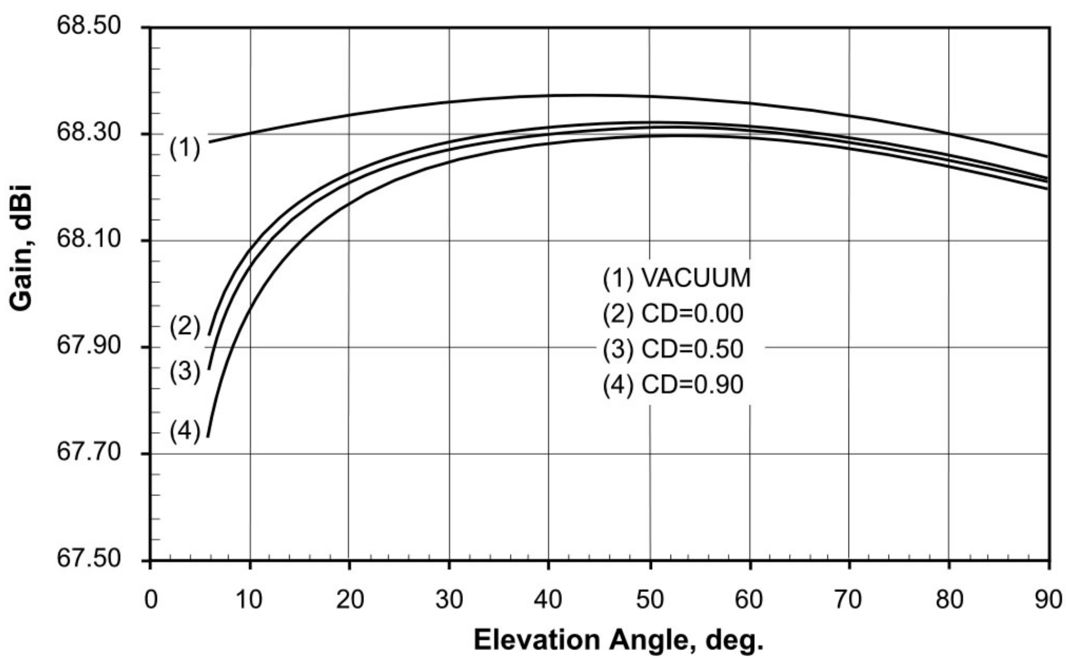


Figure 11. DSS 54 (Madrid) X-Band Receive Gain versus Elevation Angle, X/Ka-Mode (S/X Dichroic Retracted), 8420 MHz

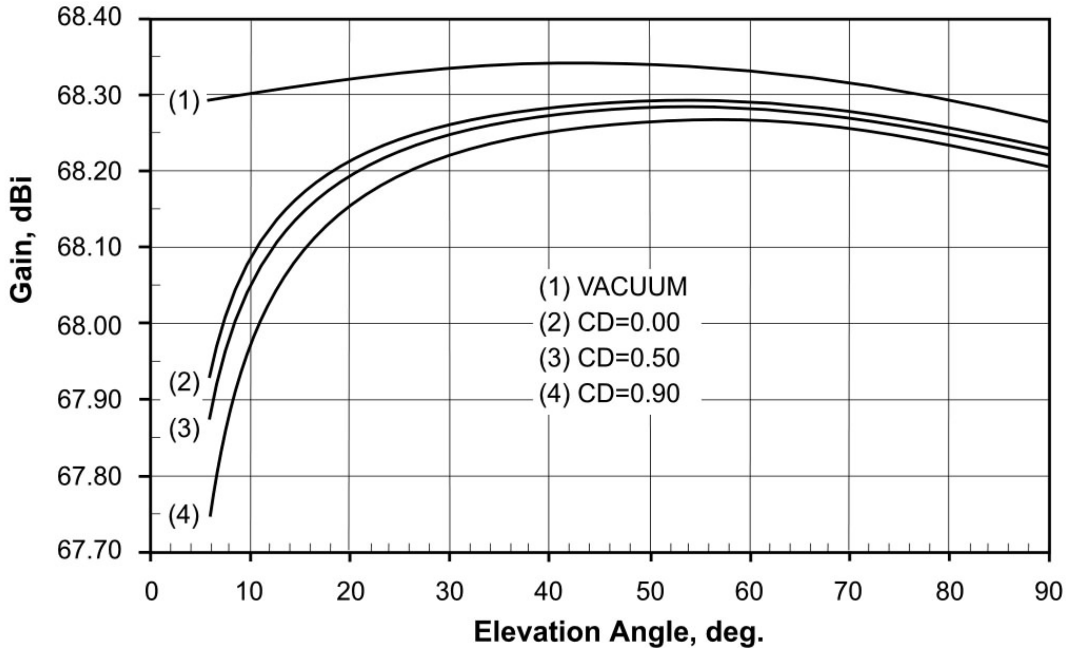


Figure 12. DSS 55 (Madrid) X-Band Receive Gain versus Elevation Angle, X/Ka-Mode, 8420 MHz

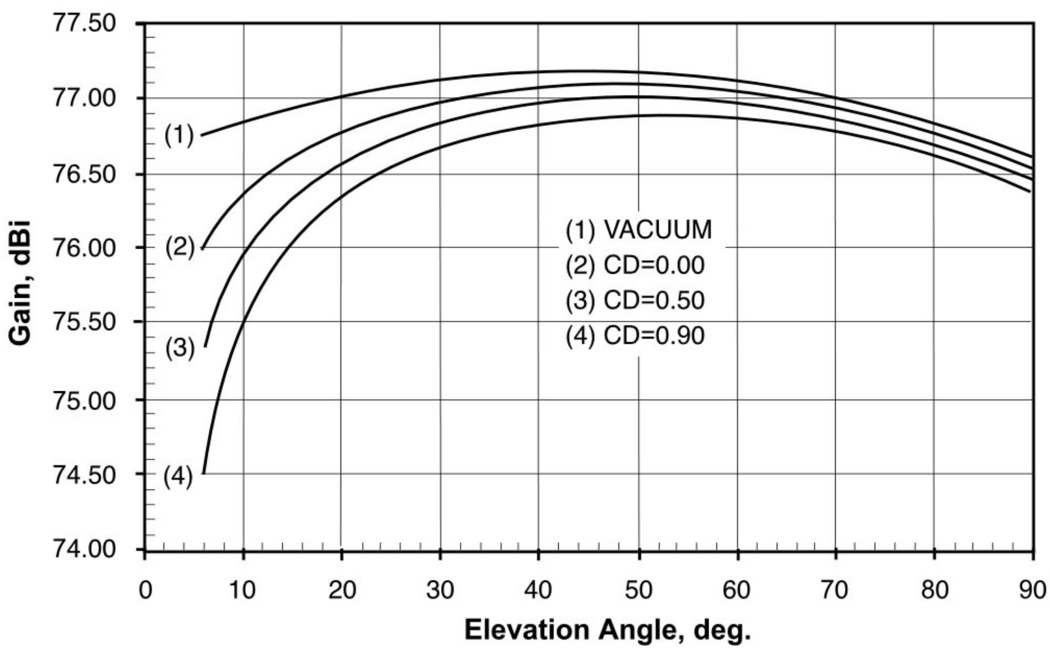


Figure 13. DSS 24 (Goldstone) K-Band Receive Gain versus Elevation Angle, K-Only Mode (S/K Dichroic Retracted), 26000 MHz

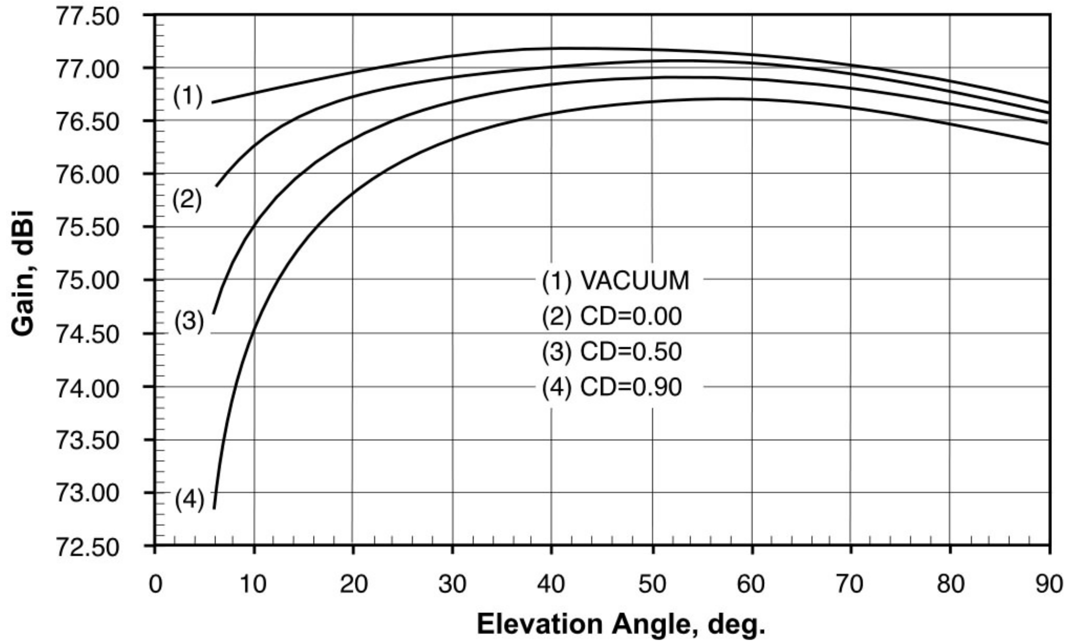


Figure 14. DSS 34 (Canberra) K-Band Receive Gain versus Elevation Angle, K-Only Mode (S/K Dichroic Retracted), 26000 MHz

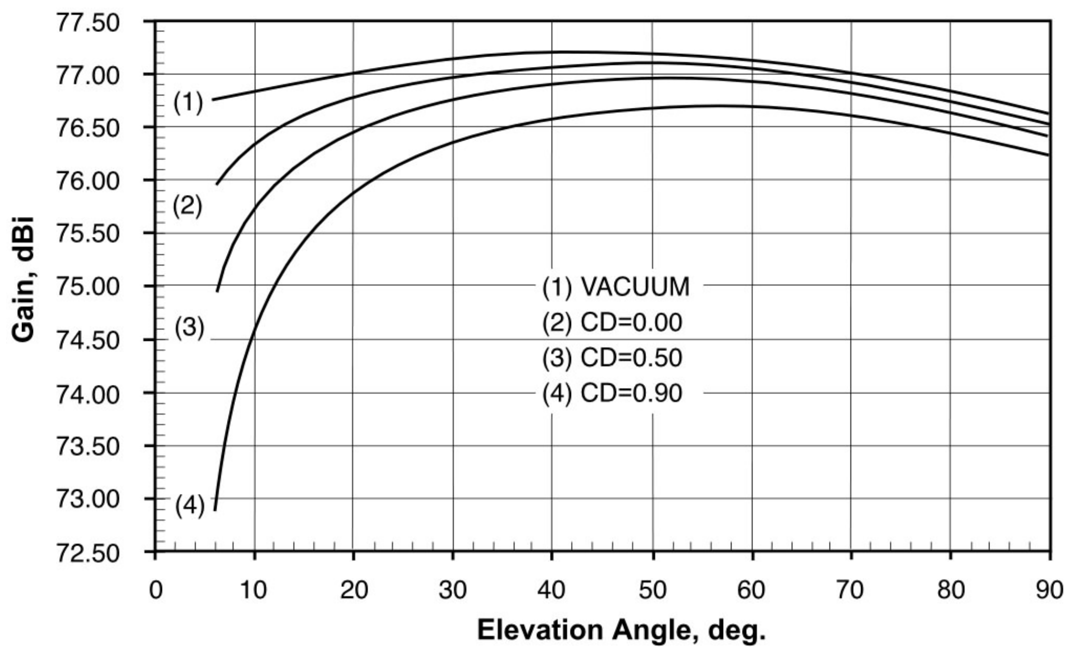


Figure 15. DSS 54 (Madrid) K-Band Receive Gain versus Elevation Angle, K-Only Mode (S/K Dichroic Retracted), 26000 MHz

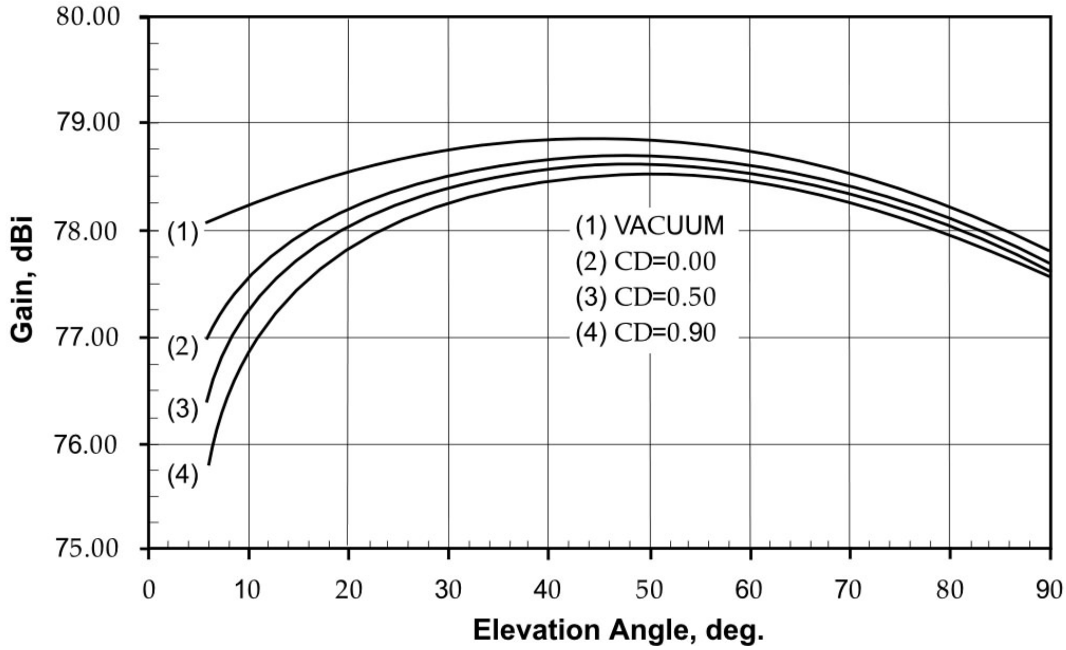


Figure 16. DSS 25 (Goldstone) Ka-Band Receive Gain versus Elevation Angle, X/Ka-Mode (X/Ka Dichroic In-Place), 32000 MHz

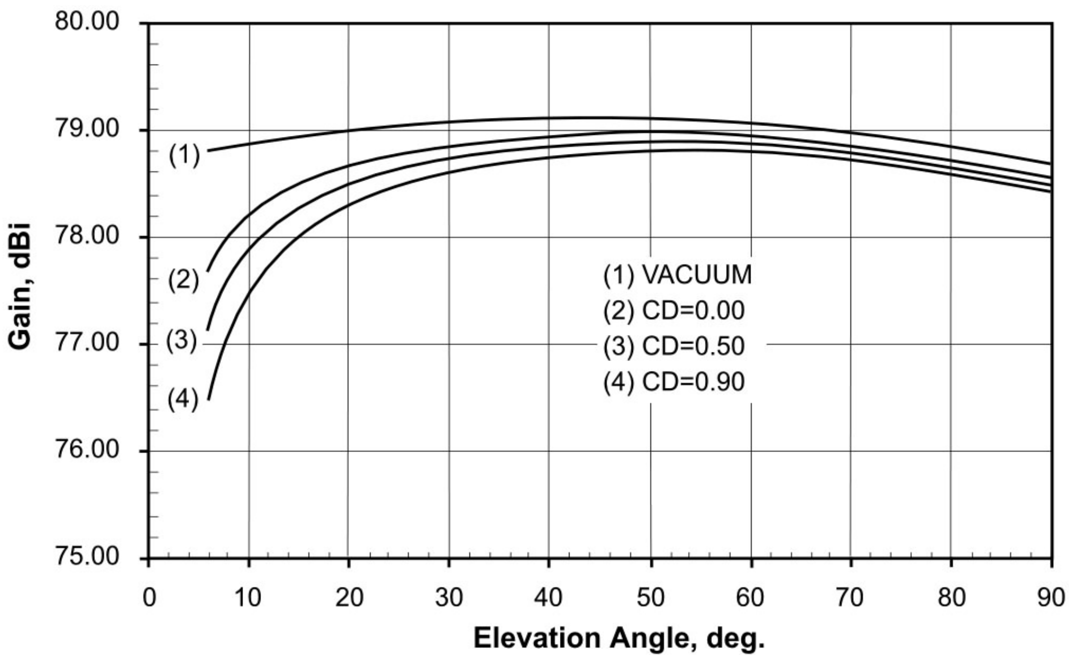


Figure 17. DSS 26 (Goldstone) Ka-Band Receive Gain versus Elevation Angle, X/Ka-Mode, 32000 MHz

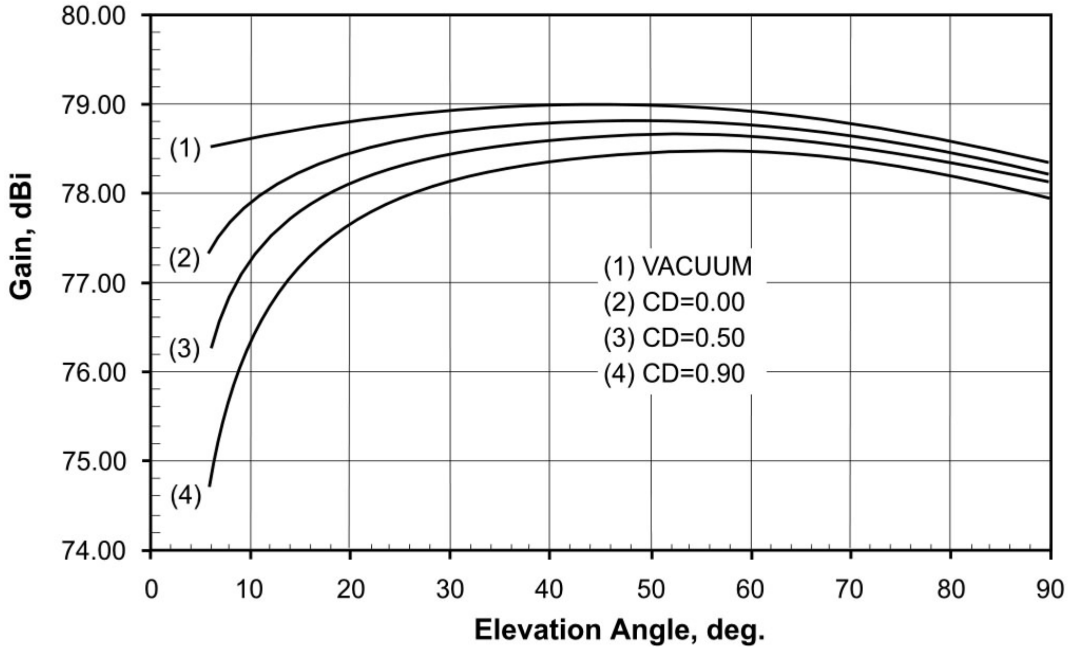


Figure 18. DSS 34 (Canberra) Ka-Band Receive Gain versus Elevation Angle, X/Ka-Mode, 32000 MHz

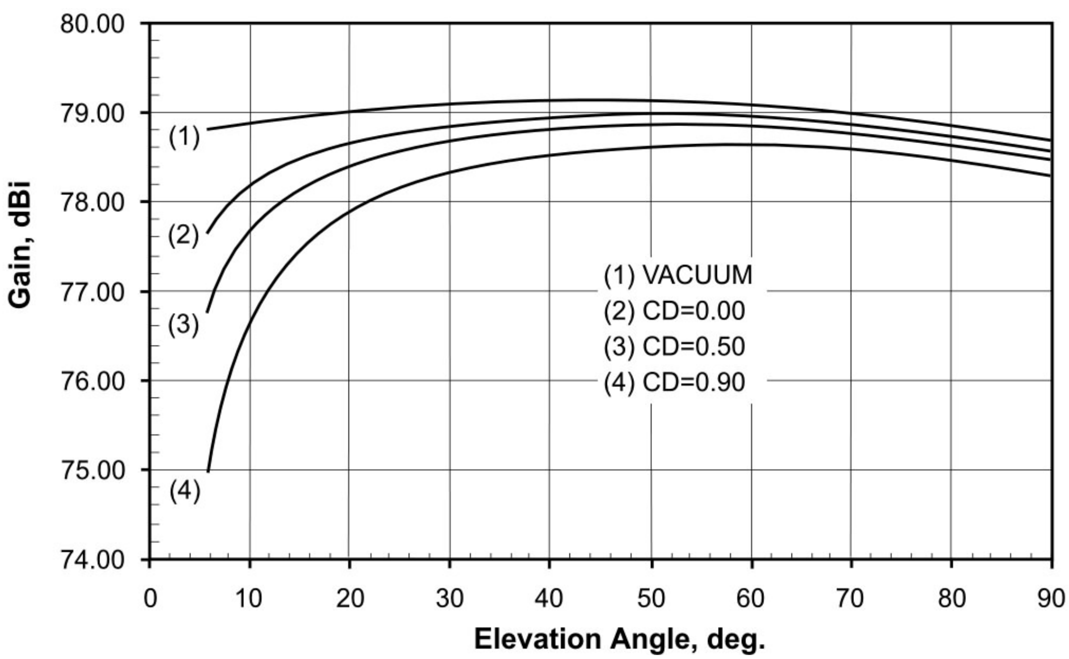


Figure 19. DSS 55 (Madrid) Ka-Band Receive Gain versus Elevation Angle, X/Ka-Mode, 32000 MHz

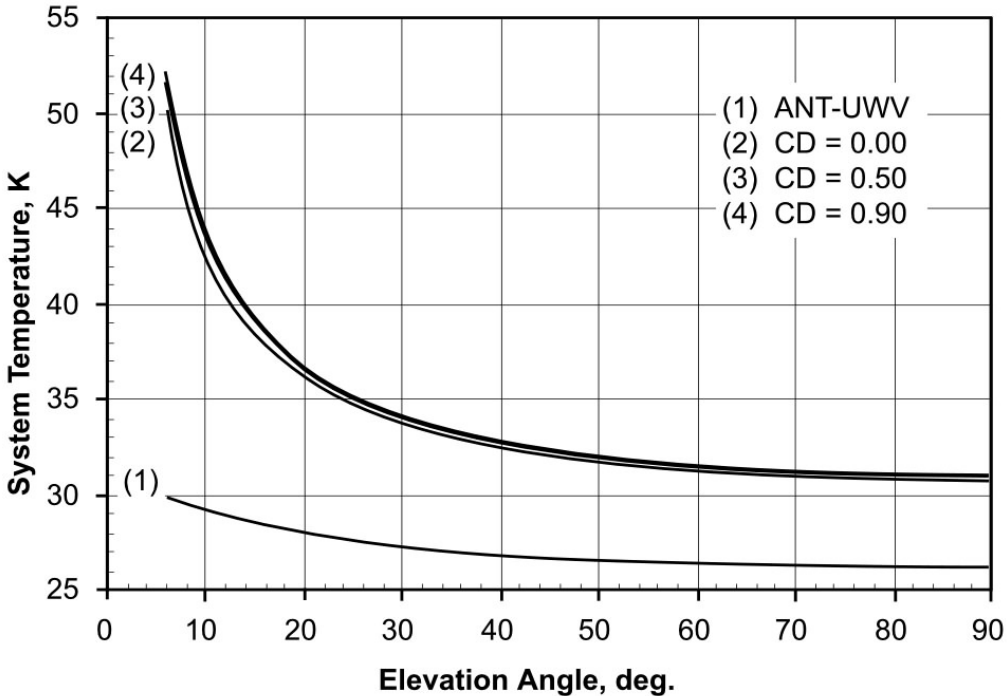


Figure 20. DSS 24 (Goldstone) S-Band System Temperature versus Elevation Angle, S/X-Mode (S/X Dichroic In Place), Non-Diplexed Path

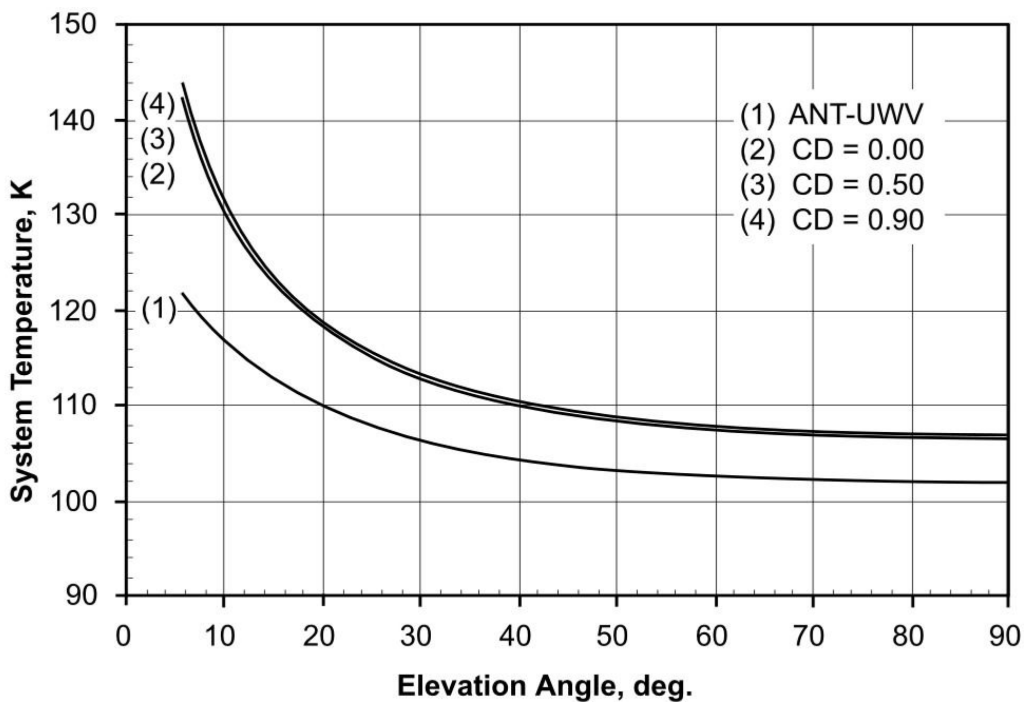


Figure 21. DSS 27 (Goldstone) S-Band System Temperature versus Elevation Angle, Diplexed Path

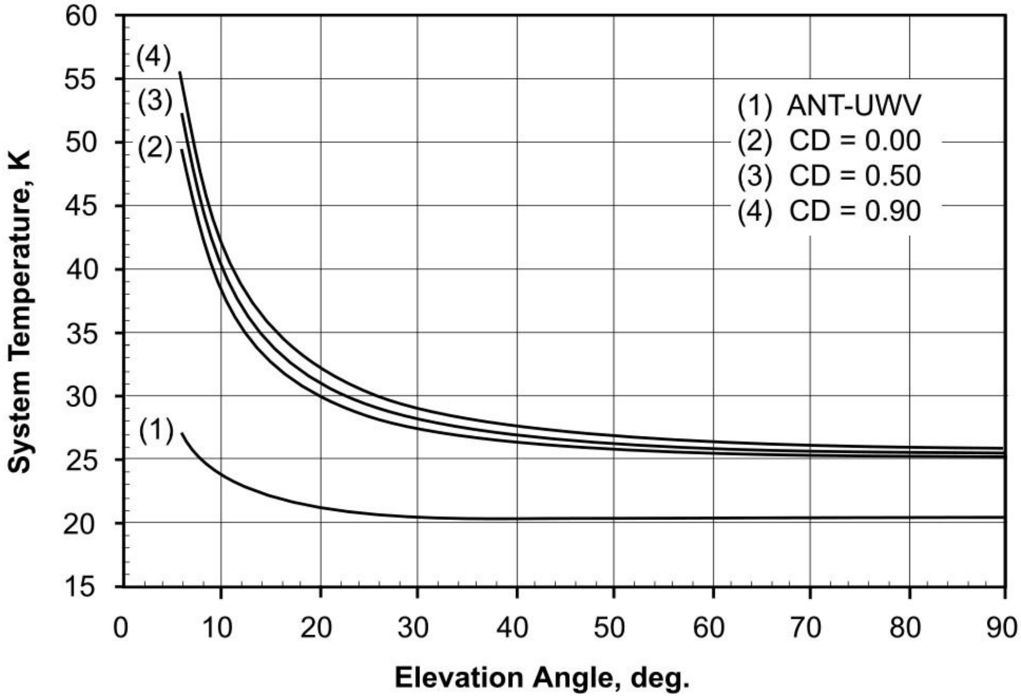


Figure 22. DSS 25 (Goldstone) X-Band System Temperature versus Elevation Angle, X/Ka-mode (X/Ka Dichroic In Place), Non-Diplexed Path, MASER-1

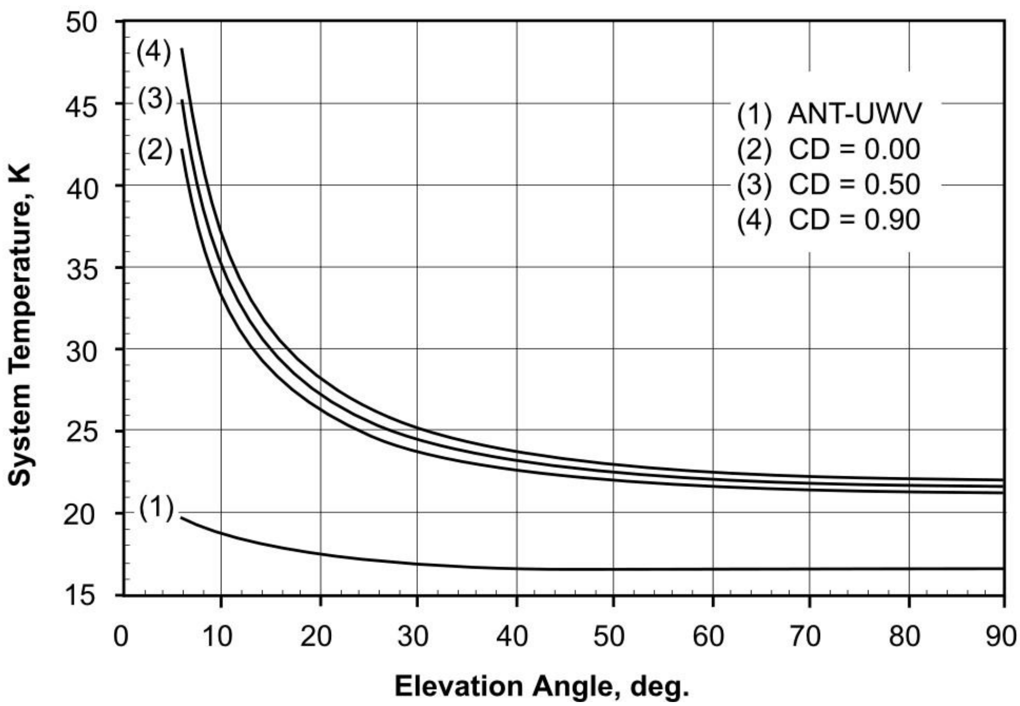


Figure 23. DSS 26 (Goldstone) X-Band RCP System Temperature versus Elevation Angle, X/Ka-Mode

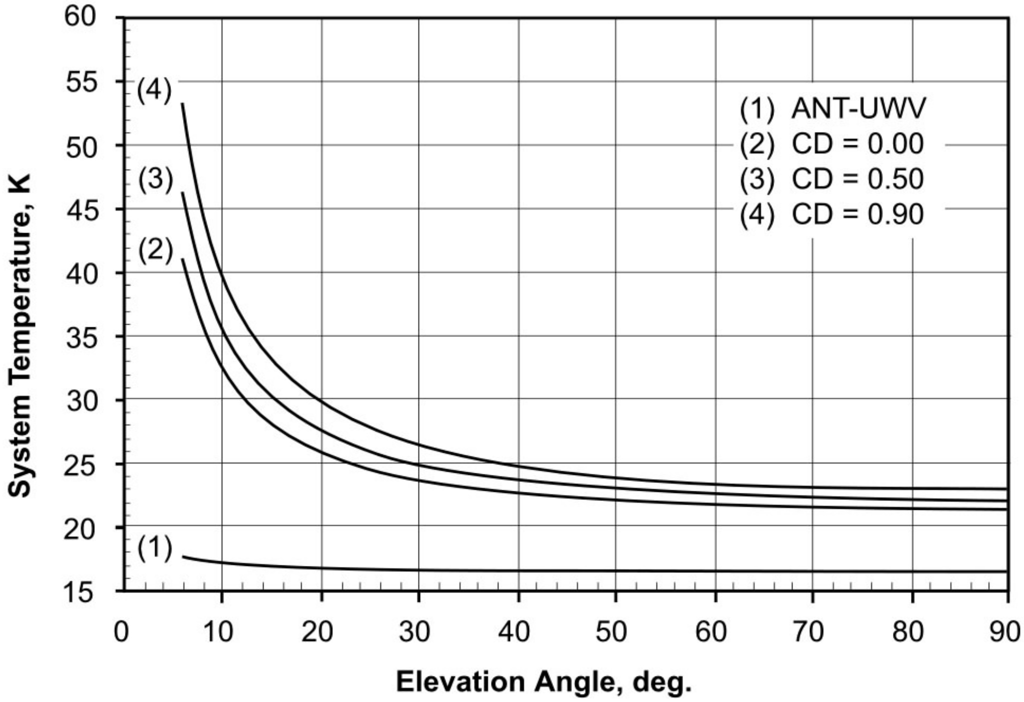


Figure 24. DSS 34 (Canberra) X-Band RCP System Temperature versus Elevation Angle, X/Ka-Mode (S/X Dichroic Retracted), 8420 MHz

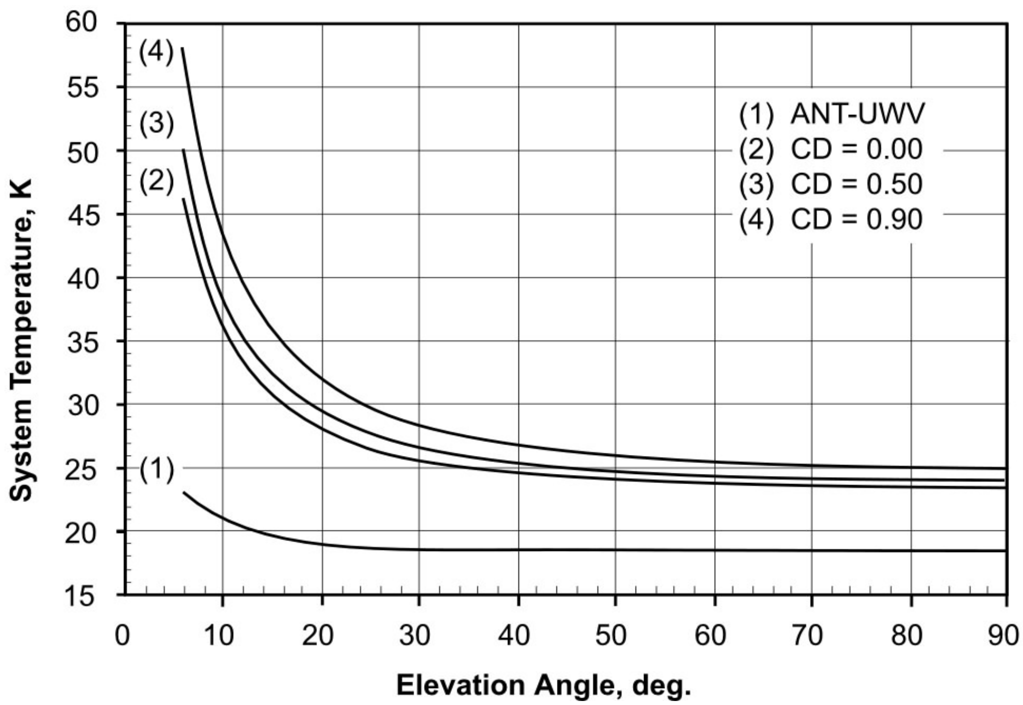


Figure 25. DSS 54 (Madrid) X-Band RCP System Temperature versus Elevation Angle, X/Ka-Mode (S/X Dichroic Retracted), 8420 MHz

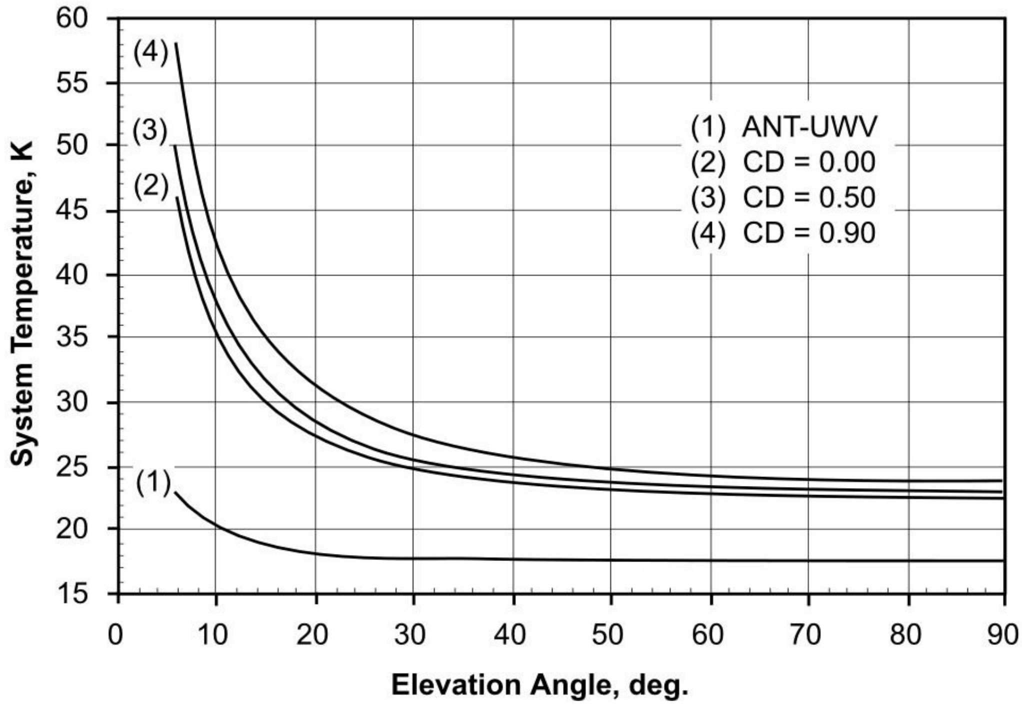


Figure 26. DSS 55 (Madrid) X-Band RCP System Temperature versus Elevation Angle, X/Ka-Mode

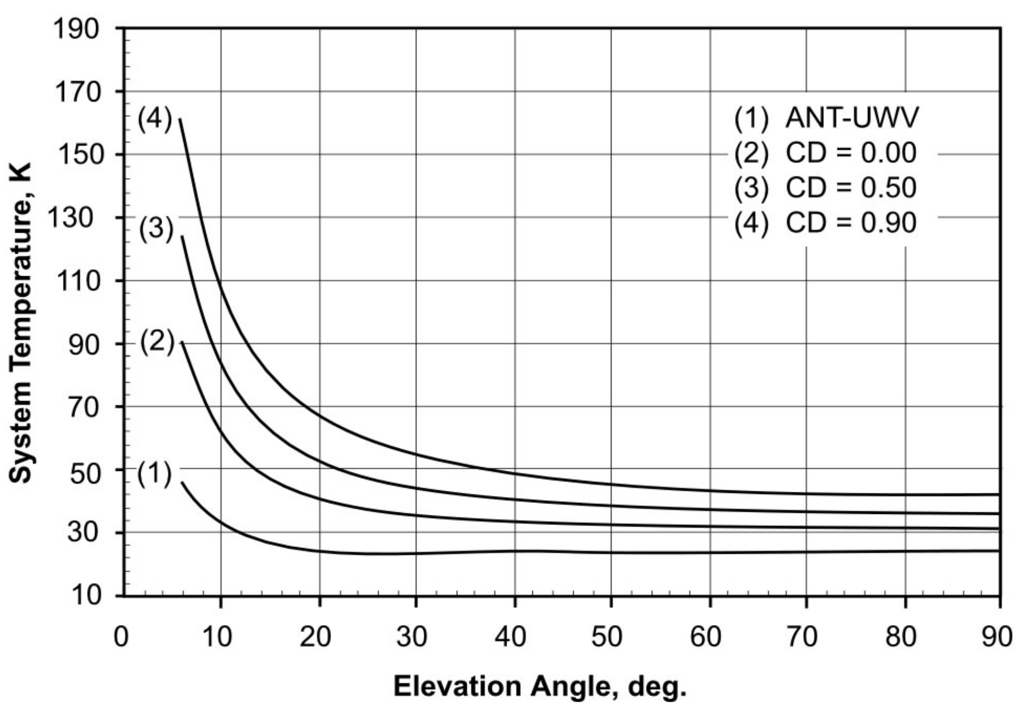


Figure 27. DSS 24 (Goldstone) K-Band RCP System Temperature versus Elevation Angle, K-only Mode (S/K Dichroic Retracted), 26000 MHz

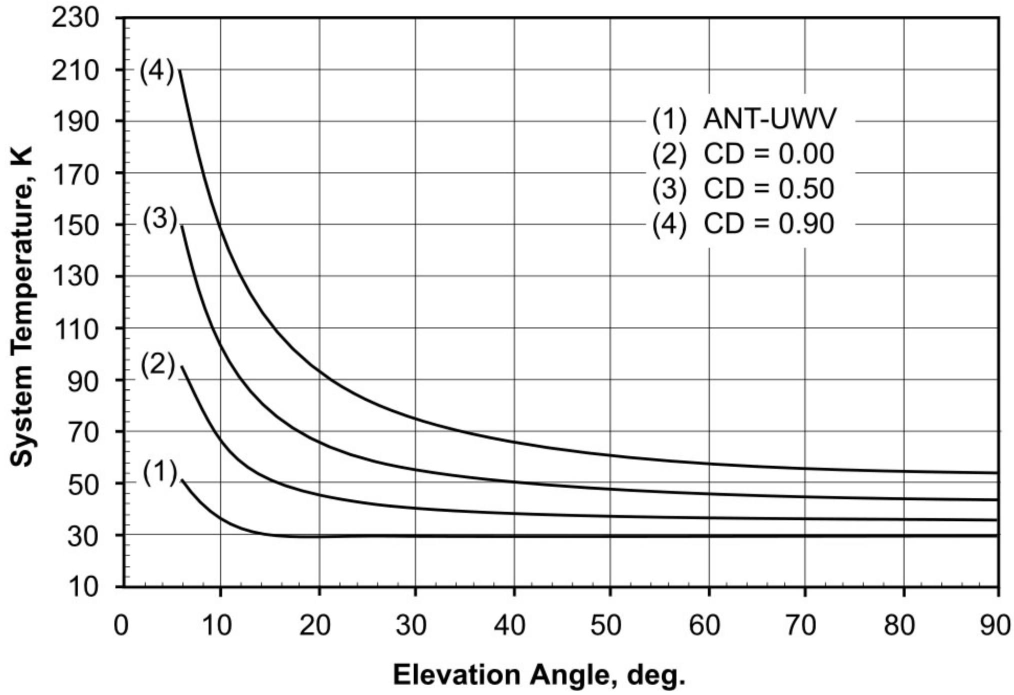


Figure 28. DSS 34 (Canberra) K-Band RCP System Temperature versus Elevation Angle, K-only Mode (S/K Dichroic Retracted), 26000 MHz

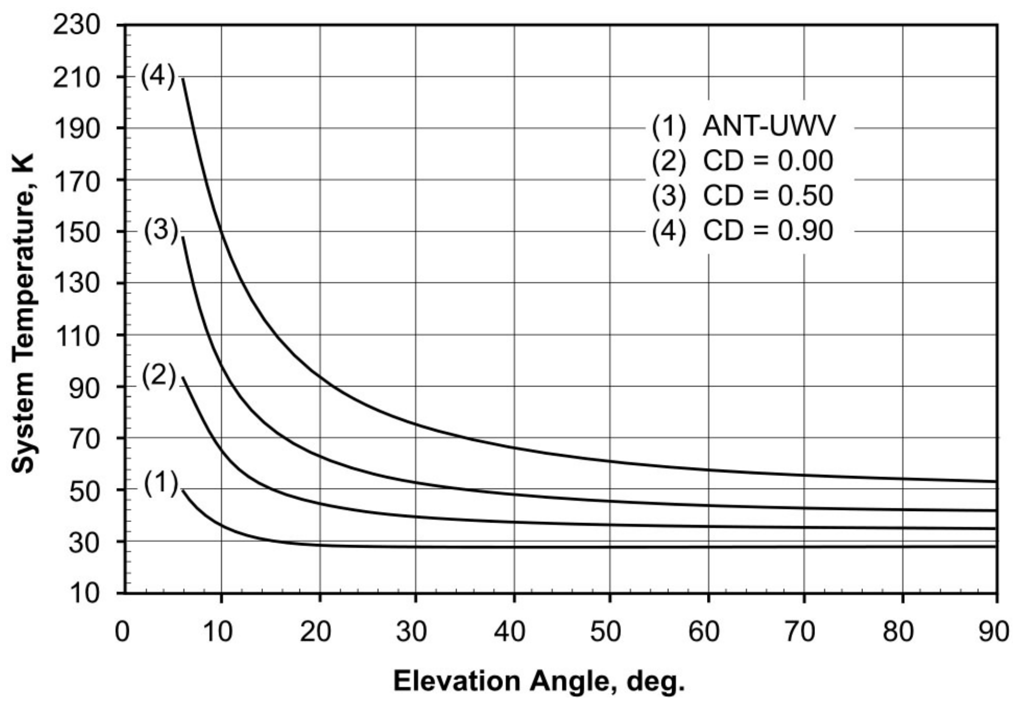


Figure 29. DSS 54 (Madrid) K-Band RCP System Temperature versus Elevation Angle, K-only Mode (S/K Dichroic Retracted), 26000 MHz

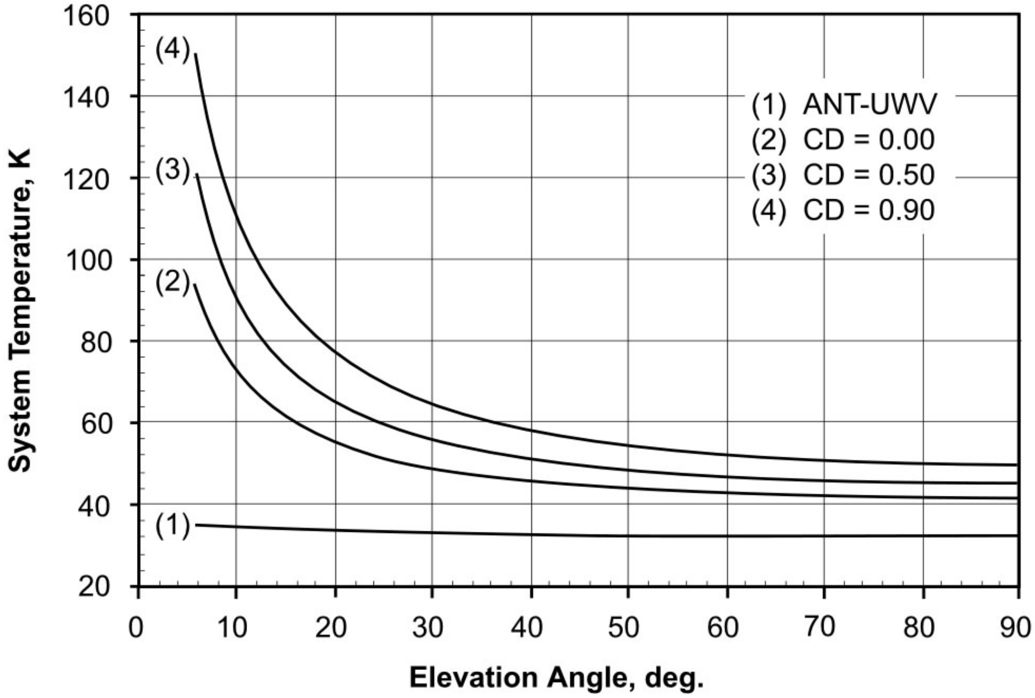


Figure 30. DSS 25 (Goldstone) Ka-Band System Temperature versus Elevation Angle, X/Ka-Mode (X/Ka Dichroic in Place)

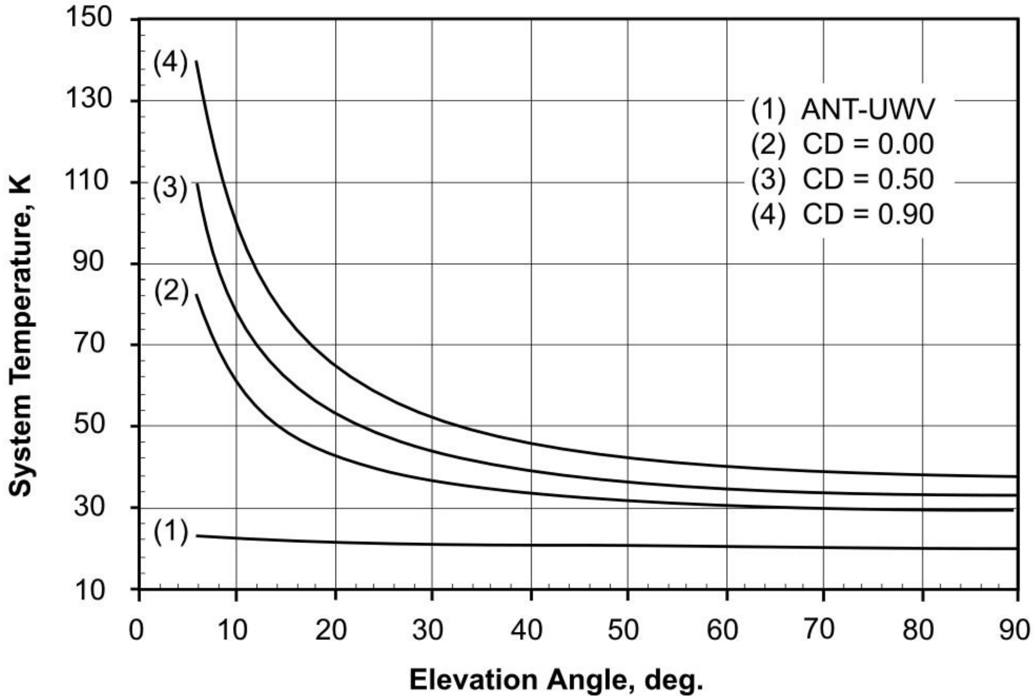


Figure 31. DSS 26 (Goldstone) Ka-Band RCP System Temperature versus Elevation Angle, X/Ka-Mode

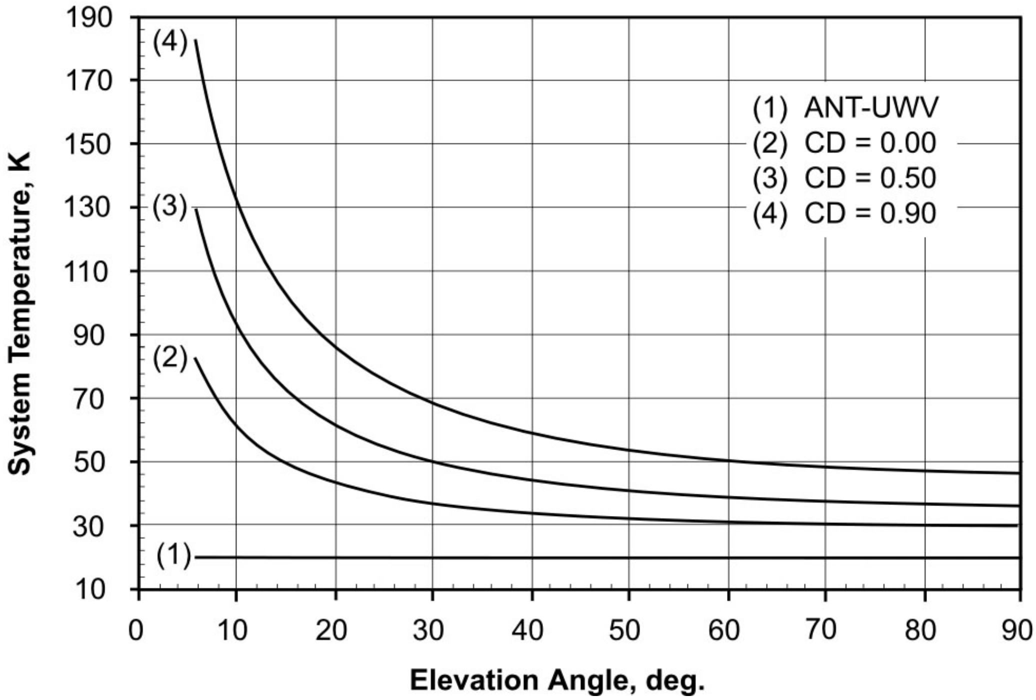


Figure 32. DSS 34 (Canberra) Ka-Band RCP System Temperature versus Elevation Angle, X/Ka-Mode

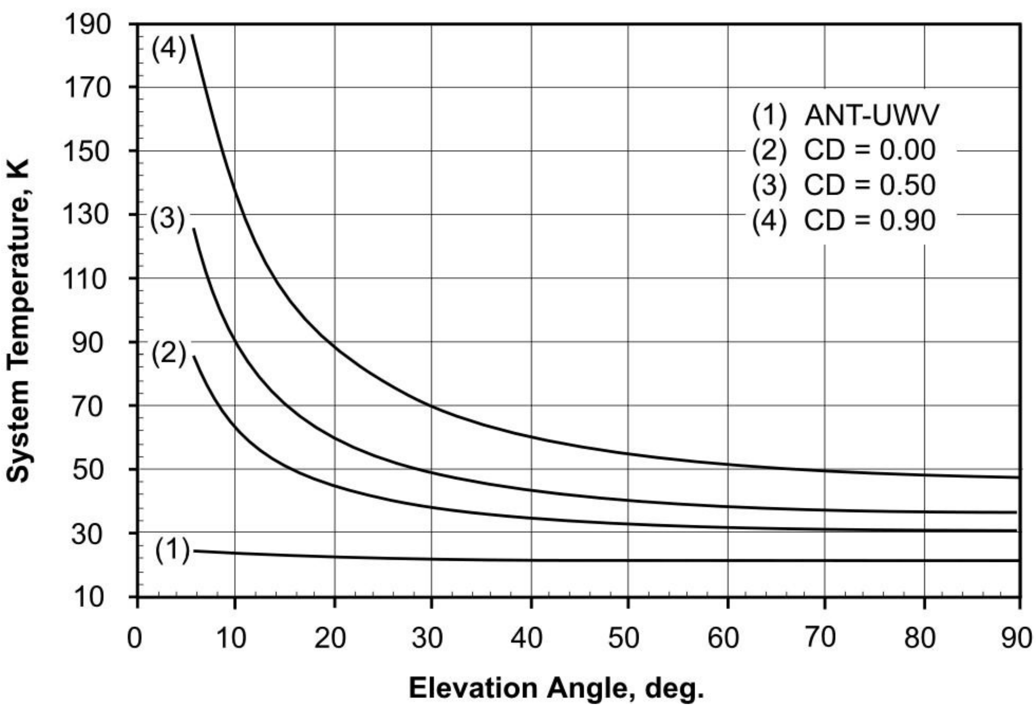


Figure 33. DSS 55 (Madrid) Ka-Band RCP System Temperature versus Elevation Angle, X/Ka-Mode

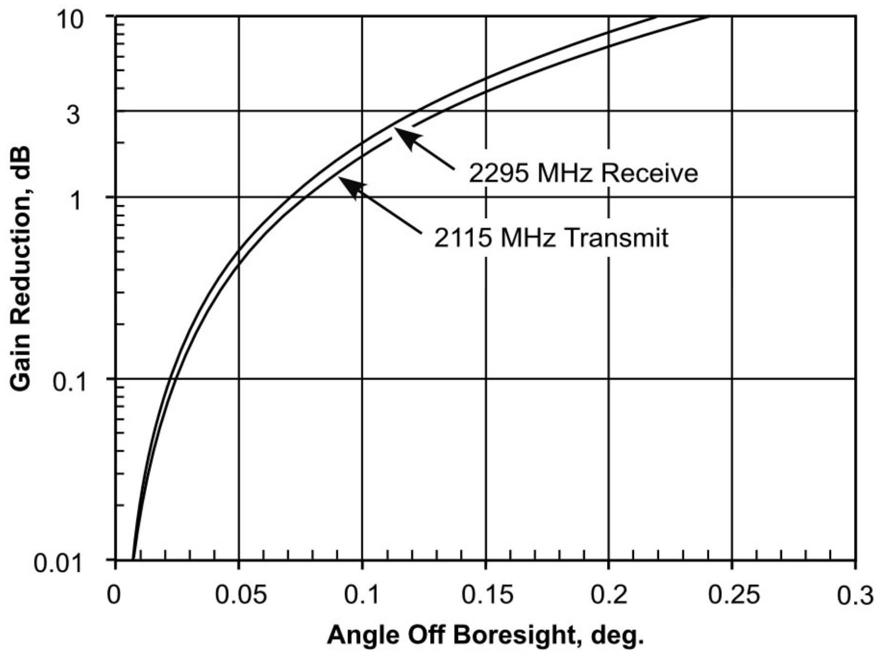


Figure 34. S-Band Gain Reduction versus Angle off Boresight

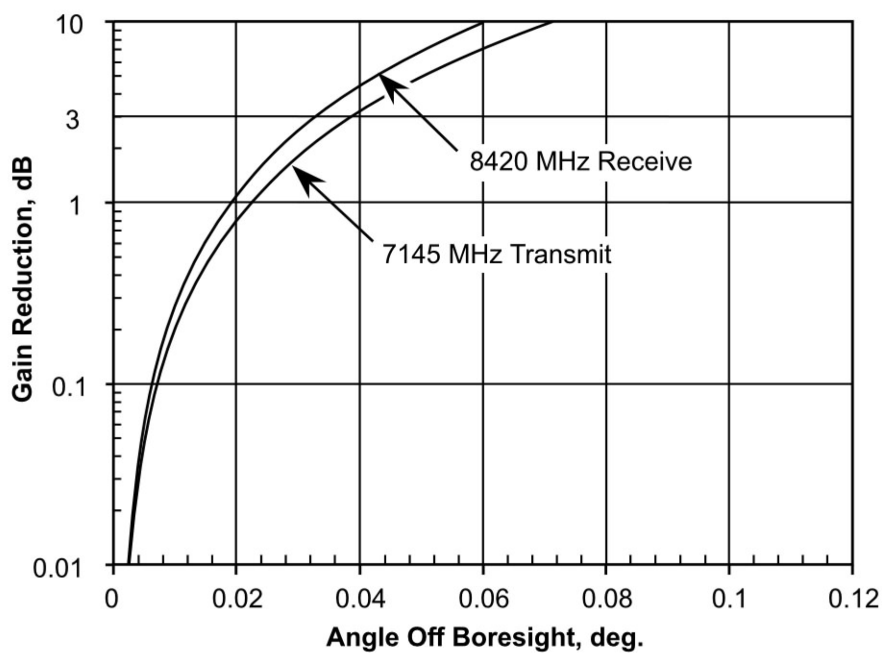


Figure 35. X-Band Gain Reduction versus Angle off Boresight

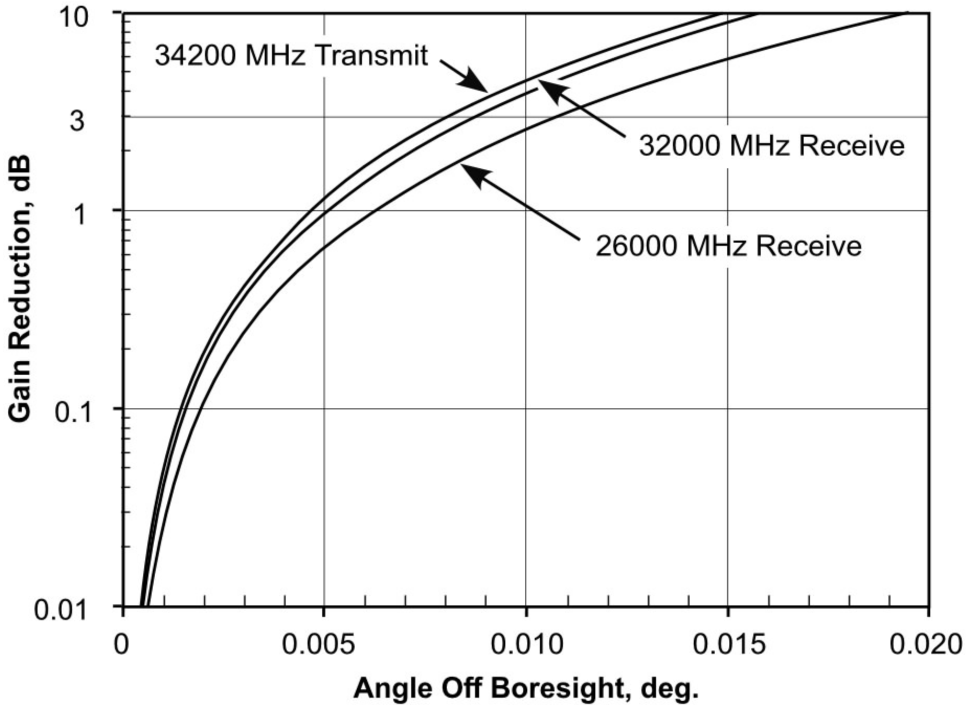


Figure 36. K- and Ka-Band Gain Reduction versus Angle off Boresight

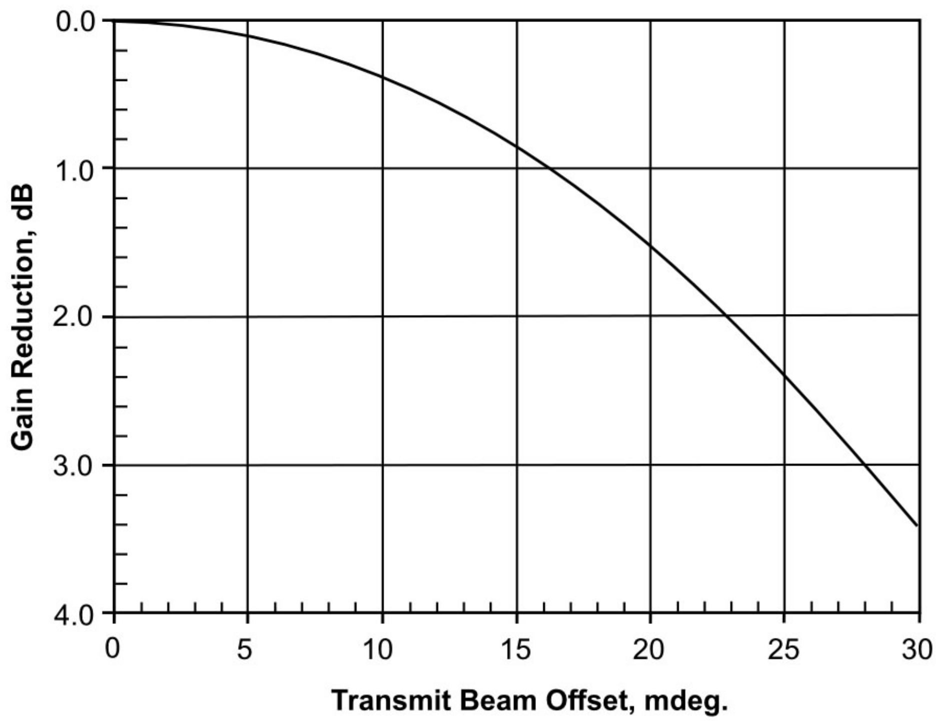


Figure 37. Ka-Band Transmit Gain Reduction Due to Aberration Correction

Appendix A
Equations for Modeling

A.1 Equations for Gain Versus Elevation Angle

The following equation can be used to generate S-, X-, and Ka-Band transmit and receive gain versus elevation angle curves. Examples of these curves for selected stations and configurations are shown in Figures 6–16. See paragraph 2.1.1.1 for frequency effect modeling and module 105 for atmospheric attenuation at weather conditions other than 0%, 50% and 90% cumulative distribution.

$$G(\theta) = G_0 - G_1(\theta - \gamma)^2 - \frac{A_{zen}}{\sin\theta}, \text{ dBi} \tag{A-1}$$

where

θ	=	antenna elevation angle (deg.) $6 \le \theta \le 90$
G_0, G_1, γ	=	parameters from Tables A1, A2, and A3
A_{zen}	=	zenith atmospheric attenuation, dB, from Table A-4 or from Tables 10-18 in module 105

A.2 Equations for System Temperature Versus Elevation Angle

The following equation can be used to generate S-, X, and Ka-Band system temperature versus elevation angle curves. Examples of these curves are shown in Figures 17–27. See module 105 for atmospheric attenuation at weather conditions other than 0%, 50% and 90% cumulative distribution.

System operating noise temperature:

$$T_{op}(\theta) = T_{AMW} + T_{sky} \tag{A2}$$

Antenna-Microwave noise contribution:

$$T_{AMW} = T_1 + T_2 e^{-a\theta} \tag{A3}$$

Sky noise contribution:

$$T_{sky} = T_{atm}(\theta) + T'_{CMB}(\theta) \tag{A4}$$

Atmospheric attenuation:

$$A(\theta) = \frac{A_{zen}}{\sin(\theta)}, \text{ dB} \qquad \text{(A5)}$$

Atmospheric loss factor:

$$L(\theta) = 10^{\frac{A(\theta)}{10}}, \text{ dimensionless, } >1.0 \tag{A6}$$

Atmosphere mean physical temperature:

$$T_p = 255 + 25 \times CD, \text{ K} \tag{A7}$$

Atmospheric noise contribution:

$$T_{atm}(\theta) = T_p\left[1 - \frac{1}{L(\theta)}\right], \text{ K} \tag{A8}$$

Effective cosmic background noise:

$$T'_{CMB}(\theta) = \frac{T_{CMB}}{L(\theta)}, \text{ K} \tag{A9}$$

where

θ = antenna elevation angle (deg.), $6 \leq \theta \leq 90$

T_1, T_2, a = antenna-microwave noise temperature parameters from Tables A-1, A-2, and A-3

A_{zen} = zenith atmospheric attenuation, dB, from Table A-4 or from Tables 10 through 18 in Module 105 as a function of frequency, station, and cumulative distribution (*CD*)

CD = cumulative distribution, $0 \leq CD \leq 0.99$, used to select A_{ZEN} from Table A-4 or from Tables 10 through 18 in Module 105

T_{CMB} = 2.725 K, cosmic microwave background noise temperature

A.3 Equation for Gain Reduction Versus Pointing Error

The following equation can be used to generate gain reduction versus pointing error curves examples of which are depicted in Figures 28, 29, and 30.

$$\Delta G(\theta) = 10 \log\left(e^{\frac{2.773\theta^2}{HPBW^2}} \right), \text{ dB} \qquad \text{(A-3)}$$

where

θ = pointing error, deg

$HPBW$ = half-power beamwidth (from Tables 2 through 8)

A.4 Equation for Transmit Aberration Gain Reduction

The following equation can be used to generate the Ka-Band transmit gain reduction curve depicted in Figure 31.

$$\Delta G(\phi) = -0.0038\phi^2, \text{ dB} \qquad \text{(A-4)}$$

where

ϕ = transmit beam offset, mdeg

Table A-1. S-Band Vacuum Gain and Antenna-Microwave Noise Temperature Parameters, Referenced to Feedhorn Aperture

Station and Configuration	Vacuum Gain Parameters				Antenna-Microwave Noise Temperature Parameters			Figures
	G_0† Transmit	G_0† Receive	G_1	γ	T_1	T_2	a	
DSS 24 (Goldstone)								
S/X, HEMT-1, RCP or LCP, Non-Diplexed	—	56.87	0.000032	90.0	26.04	5.2	0.05	6, 20
S/X, HEMT-1, RCP or LCP, Diplexed	56.25	56.87	0.000032	90.0	33.41	5.6	0.05	
DSS 27 (Goldstone)								
S-Only, R/T HEMT-1, RCP or LCP, Diplexed	54.34	55.04	0.000040	90.00	101.67	28.7	0.061	7, 21
DSS 34 (Canberra)								
S/X, HEMT-1, RCP or LCP, Non-Diplexed	—	56.83	0.000042	43.19	24.88	20.0	0.16	
S/X, HEMT-1, RCP or LCP, Diplexed	56.27	56.83	0.000042	43.19	34.46	20.0	0.16	
DSS 54 (Madrid)								
S/X, HEMT-1, RCP or LCP, Non-Diplexed	—	56.83	0.000042	45.00	25.72	12.0	0.08	
S/X, HEMT-1, RCP or LCP, Diplexed	56.27	56.83	0.000042	45.00	35.34	12.0	0.08	

Notes:

† G_0 values are nominal at the frequency specified in Tables 2, 3, 6, or 9. Other parameters apply to all frequencies within the same band. The nominal S-band uplink frequency at DSSs-24, -34, and -54 is 2115 MHz. The nominal S-band uplink frequency at DSS 27 is 2070 MHz. The nominal S-band downlink frequency at DSSs-24, -34, and -54 is 2295 MHz. The nominal S-band downlink frequency at DSS 27 is 2250 MHz.

Table A-2. X-Band Vacuum Gain and Antenna-Microwave Noise Temperature Parameters, Referenced to Feedhorn Aperture

Station and Configuration	**Vacuum Gain Parameters**				**Antenna-Microwave Noise Temperature Parameters**			**Figures**
	G_0† Transmit	G_0† Receive	G_1	γ	T_1	T_2	a	
DSS 24 (Goldstone)								
X-Only, MASER-1, RCP or LCP, Non-Diplexed	—	68.24	0.000027	51.50	21.28	1.5	0.11	
X-Only, MASER-1, RCP or LCP, Diplexed	67.06	68.24	0.000027	51.50	30.39	2.9	0.11	
S/X, MASER-1, RCP or LCP, Non-Diplexed	—	68.19	0.000027	51.50	22.72	1.5	0.11	
S/X, MASER-1, RCP or LCP, Diplexed	—	68.19	0.000027	51.50	31.89	2.9	0.11	
DSS 25 (Goldstone)								
X/Ka, MASER-1, RCP or LCP, Non-Diplexed	—	68.50	0.000028	47.50	20.20	16.4	0.15	8, 22
X/Ka, HEMT-1, RCP or LCP, Non-Diplexed	—	68.50	0.000028	47.50	35.06	17.4	0.15	
X/Ka, MASER-1, RCP or LCP, Diplexed	67.32	68.50	0.000028	47.50	29.26	19.0	0.15	
X/Ka, HEMT-1, RCP or LCP, Diplexed	67.39	68.50	0.000028	47.50	44.88	20.1	0.15	
DSS 26 (Goldstone)								
X/Ka, HEMT-1, RCP, Diplexed	66.93	68.29	0.000059	42.46	16.29	5.2	0.08	9, 23
X/Ka, HEMT-2, LCP, Diplexed	66.93	68.29	0.000059	42.46	15.43	5.2	0.08	

Notes:

† G_0 values are nominal at the frequency specified in Tables 4, 7, and 8. Other parameters apply to all frequencies within the same band. The nominal X-band uplink frequency is 7145 MHz. The nominal X-band downlink frequency is 8420 MHz.

Table A-2. X-Band Vacuum Gain and Antenna-Microwave Noise Temperature Parameters, Referenced to Feedhorn Aperture (Continued)

Station and Configuration	Vacuum Gain Parameters				Antenna-Microwave Noise Temperature Parameters			Figures
	G_0† Transmit	G_0† Receive	G_1	γ	T_1	T_2	a	
DSS 34 (Canberra)								
X/Ka, HEMT-1, RCP, Diplexed	66.97	68.33	0.000045	48.64	16.28	5.0	0.15	10, 24
X/Ka, HEMT-2, LCP, Diplexed	66.97	68.33	0.000045	48.64	16.71	5.0	0.15	
S/X, HEMT-1, RCP, Diplexed	—	68.28	0.000045	48.64	17.99	5.0	0.15	
S/X, HEMT-2, LCP, Diplexed	—	68.28	0.000045	48.64	18.43	5.0	0.15	
DSS 54 (Madrid)								
X/Ka, HEMT-1, RCP, Diplexed	67.01	68.37	0.000058	45.25	18.31	11.0	0.15	11, 25
X/Ka, HEMT-2, LCP, Diplexed	67.01	68.37	0.000058	45.25	18.31	11.0	0.15	
S/X, HEMT-1, RCP, Diplexed	—	68.32	0.000058	45.25	20.03	11.0	0.15	
S/X, HEMT-2, LCP, Diplexed	—	68.32	0.000058	45.25	20.03	11.0	0.15	
DSS 55 (Madrid)								
X/Ka, HEMT-1, RCP, Diplexed	66.98	68.34	0.000035	43.55	17.42	13.2	0.15	12, 26
X/Ka, HEMT-2, LCP, Diplexed	66.98	68.34	0.000035	43.55	17.82	13.2	0.15	

Notes:

† G_0 values are nominal at the frequency specified in Tables 4, 7, and 8. Other parameters apply to all frequencies within the same band. . The nominal X-band uplink frequency is 7145 MHz. The nominal X-band downlink frequency is 8420 MHz.

Table A-3. K-Band Vacuum Gain and Antenna-Microwave Noise Temperature Parameters, Referenced to Feedhorn Aperture

Station and Configuration	Vacuum Gain Parameters			Antenna-Microwave Noise Temperature Parameters			Figures
	G_0 Receive	G_1	γ	T_1	T_2	a	
DSS 24 (Goldstone)							
K-only, RCP, 25.5 GHz, Non-Diplexed	77.03	0.00029	45.0	24.89	100.00	0.25	
K-only, LCP, 25.5 GHz, Non-Diplexed	77.03	0.00029	45.0	30.42	100.00	0.25	
S/K, RCP, 25.5 GHz, Non-Diplexed	76.99	0.00029	45.0	35.19	100.00	0.25	
S/K, LCP, 25.5 GHz, Non-Diplexed	76.99	0.00029	45.0	40.69	100.00	0.25	
K-only, RCP, 26.0 GHz, Non-Diplexed	77.20	0.00029	45.0	24.11	100.00	0.25	13, 27
K-only, LCP, 26.0 GHz, Non-Diplexed	77.20	0.00029	45.0	29.19	100.00	0.25	
S/K, RCP, 26.0 GHz, Non-Diplexed	77.16	0.00029	45.0	29.92	100.00	0.25	
S/K, LCP, 26.0 GHz, Non-Diplexed	77.16	0.00029	45.0	34.52	100.00	0.25	
K-only, RCP, 27.0 GHz, Non-Diplexed	77.53	0.00029	45.0	23.86	100.00	0.25	
K-only, LCP, 27.0 GHz, Non-Diplexed	77.53	0.00029	45.0	28.07	100.00	0.25	
S/K, RCP, 27.0 GHz, Non-Diplexed	77.49	0.00029	45.0	33.15	100.00	0.25	
S/K, LCP, 27.0 GHz, Non-Diplexed	77.49	0.00029	45.0	37.35	100.00	0.25	

Table A-3. K-Band Vacuum Gain and Antenna-Microwave Noise Temperature Parameters, Referenced to Feedhorn Aperture (Continued)

Station and Configuration	Vacuum Gain Parameters			Antenna-Microwave Noise Temperature Parameters			Figures
	G_0 Receive	G_1	γ	T_1	T_2	a	
DSS 34 (Canberra)							
K-only, RCP, 25.5 GHz, Non-Diplexed	77.02	0.00029	48.0	26.31	100.00	0.25	
K-only, LCP, 25.5 GHz, Non-Diplexed	77.02	0.00029	48.0	27.49	100.00	0.25	
S/K, RCP, 25.5 GHz, Non-Diplexed	76.98	0.00029	48.0	37.17	100.00	0.25	
S/K, LCP, 25.5 GHz, Non-Diplexed	76.98	0.00029	48.0	37.29	100.00	0.25	
K-only, RCP, 26.0 GHz, Non-Diplexed	77.19	0.00029	48.0	27.89	100.00	0.25	14, 28
K-only, LCP, 26.0 GHz, Non-Diplexed	77.19	0.00029	48.0	28.81	100.00	0.25	
S/K, RCP, 26.0 GHz, Non-Diplexed	77.15	0.00029	48.0	33.01	100.00	0.25	
S/K, LCP, 26.0 GHz, Non-Diplexed	77.15	0.00029	48.0	33.91	100.00	0.25	
K-only, RCP, 27.0 GHz, Non-Diplexed	77.52	0.00029	48.0	24.10	100.00	0.25	
K-only, LCP, 27.0 GHz, Non-Diplexed	77.52	0.00029	48.0	24.89	100.00	0.25	
S/K, RCP, 27.0 GHz, Non-Diplexed	77.48	0.00029	48.0	34.87	100.00	0.25	
S/K, LCP, 27.0 GHz, Non-Diplexed	77.48	0.00029	48.0	34.45	100.00	0.25	

Table A-3. K-Band Vacuum Gain and Antenna-Microwave Noise Temperature Parameters, Referenced to Feedhorn Aperture (Continued)

Station and Configuration	Vacuum Gain Parameters			Antenna-Microwave Noise Temperature Parameters			Figures
	G_0 Receive	G_1	γ	T_1	T_2	a	
DSS 54 (Madrid)							
K-only, RCP, 25.5 GHz, Non-Diplexed	77.02	0.00029	45.0	27.86	100.00	0.25	
K-only, LCP, 25.5 GHz, Non-Diplexed	77.02	0.00029	45.0	26.26	100.00	0.25	
S/K, RCP, 25.5 GHz, Non-Diplexed	76.98	0.00029	45.0	38.44	100.00	0.25	
S/K, LCP, 25.5 GHz, Non-Diplexed	76.98	0.00029	45.0	36.29	100.00	0.25	
K-only, RCP, 26.0 GHz, Non-Diplexed	77.19	0.00029	45.0	28.01	100.00	0.25	15, 29
K-only, LCP, 26.0 GHz, Non-Diplexed	77.19	0.00029	45.0	27.75	100.00	0.25	
S/K, RCP, 26.0 GHz, Non-Diplexed	77.15	0.00029	45.0	33.47	100.00	0.25	
S/K, LCP, 26.0 GHz, Non-Diplexed	77.15	0.00029	45.0	32.97	100.00	0.25	
K-only, RCP, 27.0 GHz, Non-Diplexed	77.52	0.00029	45.0	25.27	100.00	0.25	
K-only, LCP, 27.0 GHz, Non-Diplexed	77.52	0.00029	45.0	24.22	100.00	0.25	
S/K, RCP, 27.0 GHz, Non-Diplexed	77.48	0.00029	45.0	35.30	100.00	0.25	
S/K, LCP, 27.0 GHz, Non-Diplexed	77.48	0.00029	45.0	33.63	100.00	0.25	

Table A-4. Ka-Band Vacuum Gain and Antenna-Microwave Noise Temperature Parameters, Referenced to Feedhorn Aperture

Station and Configuration	Vacuum Gain Parameters				Antenna-Microwave Noise Temperature Parameters			Figures
	G_0† Transmit	G_0† Receive	G_1	γ	T_1	T_2	a	
DSS 25 (Goldstone)								
Ka-Only, HEMT-1, RCP, Diplexed	79.52	79.00	0.00052	45.00	27.66	3.4	0.030	
Ka-Only, HEMT-2, RCP-error, Diplexed	—	—	—	—	27.07	3.4	0.030	
X/Ka, HEMT-1, RCP, Diplexed	79.37	78.85	0.00052	45.00	31.18	3.4	0.030	16, 30
X/Ka, HEMT-2, RCP-error, Diplexed	—	—	—	—	35.30	3.4	0.030	
DSS 26 (Goldstone)								
X/Ka, HEMT-1, RCP, Non-Diplexed	—	79.13	0.00022	44.38	19.35	5.0	0.075	17, 31
X/Ka, HEMT-2, RCP-error, Non-Diplexed	—	—	—	—	24.54	5.0	0.075	
X/Ka, HEMT-3, LCP, Non-Diplexed	—	79.13	0.00022	44.38	20.76	5.0	0.075	
DSS 34 (Canberra)								
X/Ka, HEMT-1, RCP, Non-Diplexed	—	78.98	0.00031	44.30	19.38	0.0	0.000	18, 32
X/Ka, HEMT-2, RCP-error, Non-Diplexed	—	—	—	—	23.25	0.0	0.000	
X/Ka, HEMT-3, LCP, Non-Diplexed	—	78.98	0.00031	44.30	19.61	0.0	0.000	

Notes:

† G_0 values are nominal at the frequency specified in Tables 5 and 8. Other parameters apply to all frequencies within the same band. The nominal Ka-band uplink frequency is 34300 MHz. The nominal Ka-band downlink frequency is 32000 MHz.

Table A-4. Ka-Band Vacuum Gain and Antenna-Microwave Noise Temperature Parameters, Referenced to Feedhorn Aperture

Station and Configuration	Vacuum Gain Parameters				Antenna-Microwave Noise Temperature Parameters			Figures
	G_0† Transmit	G_0† Receive	G_1	γ	T_1	T_2	a	
DSS 54 (Madrid)								
X/Ka, HEMT-1, RCP, Non-Diplexed	—	78.38	0.00020	45.00	21.80	0.0	0.000	
X/Ka, HEMT-2, RCP-error, Non-Diplexed	—	—	—	—	25.00	0.0	0.000	
X/Ka, HEMT-3, LCP, Non-Diplexed	—	78.38	0.00020	45.00	21.80	0.0	0.000	
DSS 55 (Madrid)								
X/Ka, HEMT-1, RCP, Non-Diplexed	—	79.13	0.00022	45.00	20.79	5.3	0.076	19, 33
X/Ka, HEMT-2, RCP-error, Non-Diplexed	—	—	—	—	21.97	5.3	0.076	
X/Ka, HEMT-3, LCP, Non-Diplexed	—	79.13	0.00022	45.00	19.82	5.3	0.076	

Notes:

† G_0 values are nominal at the frequency specified in Tables 5 and 8. Other parameters apply to all frequencies within the same band. The nominal Ka-band uplink frequency is 34300 MHz. The nominal Ka-band downlink frequency is 32000 MHz.

Table A-5. S-, X-, K-, and Ka-Band Zenith Atmospheric Attenuation (A_{zen})

Station	**A_{zen}, dB**			
	CD† = 0.00	**CD† = 0.25**	**CD† = 0.50**	**CD† = 0.90**
S-Band				
Goldstone	0.033	0.033	0.034	0.034
Canberra	0.036	0.036	0.036	0.037
Madrid	0.035	0.035	0.035	0.036
X-Band				
Goldstone	0.037	0.039	0.041	0.045
Canberra	0.039	0.045	0.047	0.058
Madrid	0.038	0.043	0.044	0.057
K-Band				
Goldstone	0.078	0.125	0.150	0.232
Canberra	0.084	0.176	0.212	0.387
Madrid	0.082	0.153	0.186	0.385
Ka-Band				
Goldstone	0.116	0.154	0.174	0.243
Canberra	0.124	0.208	0.238	0.397
Madrid	0.121	0.183	0.211	0.393

Notes:

† CD = cumulative distribution.